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THE TRANSFORMED CATENARY AS A FIGURE FOR ARCHES IN STONE OR METAL.*

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Written for Van Nostrand's Magazine.

THE mathematical curve known as the catenary is the curve formed by a chain, or cord of uniform section throughout,

loaded only with its own weight.

The transformed catenary, as used for the figure of an arch, is derived from the common catenary by parallel projection, and Rankine thus describes its peculiar properties as distinguished from the common catenary:

"The common catenary is the curve of equilibrium for a chain supporting a load which, whether arising from its own weight or from other weights also, is proportional upon any given arc AB of the chain to the area enclosed between that arc, the two ordinates AO, BX, and the directrix OX, which is at a depth m below the vertex, the *intensity* of the load at any point B being proportional to the ordinate y = BX."

Rankine then goes on to say that the load on the chain may be assumed to consist of an uniformly thick sheet of a homogeneous substance which, upon the arc AB would have the dimensions AO XB, and, calling the weight of an unit of area = w, he gives the horizonal tension at $A = wm^2$, m being the parameter of the curve =OA. Looking at Fig. 1, and supposing a curve *ab* made so that, whilst the horizontal abscissae are kept

the same, the vertical ordinates are all proportionately altered, so that OA: Oa :: XB: Xb, and denoting the vertical distance Oa by y_0 , and Xb by y_1 , and putting y for XB we get $m: y_0:: y: y^1$.

Then, ender these suppositions, Rankine defines the transformed catenary to be the form of equilibrium for a chain, so loaded that the weight upon any are ab is proportional to the area OabX; the intensity of load at any point b being proportionate to the ordinate Xb, all the vertical forces thus being altered in the ratio y_0 : m, and the horizontal forces remaining the same. The following equations are then given, upon which calculations may be based:

H the horizontal tension at $a=icm^2$, as in the catenary.

Intensity of load at

stead:

$$b = wy^{1} = \frac{voy_{0}}{2} \left(e^{\frac{x}{m}} + e^{-\frac{x}{m}} \right)$$

x being the abscissa OX and $e^{\frac{\pi}{m}}$ and $e^{-\frac{\pi}{m}}$

being the Naperian anti-logarithm of $\frac{x}{y}$ and the reciprocal which require a table of hyperbolic logarithms in using; but the following formula may be used in-

^{*} The calculations in this paper are not absolutely accurate, but sufficiently so for practical purposes.

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$$e^{\frac{x}{m}} = 10^{.4343} \frac{x}{m} \text{ and } e^{-\frac{x}{m}} = \frac{1}{10^{.4343} \frac{x}{m}}$$

The load between

$$\alpha$$
 and $b = P = \frac{wmy_0}{2} \left(e^{\frac{x}{m}} - e^{-\frac{x}{m}} \right)$

The tension at $b = \sqrt{P^2 + H^2}$

The principal use of the transformed catenary, says Rankine, is as a figure for arches, the curve being inverted, and tensions becoming thrusts. Such an arch is suited to sustain vertical loads of an intensity proportionate to the vertical ordinate at each point, the intrados being formed to the curve of equilibrium, and the extrados of the arch may be either a horizontal line or another transformed catenary. If horizonal, it necessarily coincides with the directrix OX. very certain that the majority of arches, in stone especially, that have ever been constructed are not of the form of an arch of equilibrium. Circular arcs have almost wholly been employed for such arches as do not approximate to the hydrostatic arch, i. e., elliptical arches. No doubt the thickness of the arch-rings of most arches is so great that a curve of equilibrium may be drawn within the ring, and at a safe distance within it, probably within the middle third of the thickness, as recommended by Rankine, i. e., of course for arches not exceeding 120°. It is by no means, however, to be taken for granted, even if the curve of equilibrium do fall outside the theoretical safe limit, that "the stability of such arches is either now precarious, or must have been precarious while the mortar was fresh," as Rankine has stated. If arches consisted only of the arch-ring, pure and simple, this would no doubt hold good, but before the centering is struck it is usual to build in the backing, oftentimes, too, level with the crown of the arch, or to fill in the spandrils with a sufficiency of walling well bound in with the arch-ring proper, thus preventing any movement of the arch, either towards collapse inwards or bursting outwards; and an arch thus well built would stand without the arch-ring proper, which is but a portion of a well-connected whole, and may be said to be the arch proper by courtesy alone.

It is, however, always more satisfac-

tory to the engineer to know that the structures he designs contain within themselves the elements of stability apart from the stability which springs from the faithful execution of the work of the mason or bricklayer, or the use of the best metal; and it is probable that the use of the inverted transformed catenary would have been more common if the mode of making the necessary calculations had been explained by Rankine more clearly than has been the case. It appears to the writer that the work of Rankine has been to grasp the natural laws bearing on the general subject of engineering, and formulate the same without making any attempt to elucidate the valuable information for the benefit of the more immediately practical man. Rankine's works want translating into a simpler form for daily use; the absolutely needful grain requires extracting from the mathematical envelope which, however interesting to the mere student of form, is worthless as an aid for the majority of our constructing engineers.

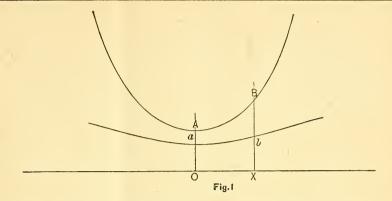
Let us then, by taking an example, endeavor to show how the transformed catenary may be found for a given arch. In practice, when an arch is to be built, it is probable that two levels would be given from which little or no deviation could be allowed.. These two would be the roadway surface over the crown of the arch and the points of springing. To determine a curve a third point would be required—the vertex of the arch, i. e., the distance of the intrados at the crown from the road surface or Oa. (Fig. 1.) Knowing these three points we should require, in order to find the form of the transformed catenary, the modulus, or parameter m, of the catenarian curve from which our arch is to be transformed by alteration of the vertical ordinates.

Calling, as before, $y_0 = Oa$, the depth of crown below the horizonal ox, and y_1 the ordinate, Xb at the point of support b distant x = OX = the half span of the bridge from the vertex a, we have,

$$M = \frac{X}{\text{hyp. log.} \left(\frac{y_1}{y_0} + \sqrt{\frac{y_1^2}{y_0^2}} - 1\right)} . (1)$$

and knowing the modulus m, we may then calculate readily our different stresses, &c.

Let us take as our data a stone arch of



180 feet span; then half span= x_1 =90. Let the height Xb (Fig. 1) be assumed

to be 42 feet; then, y = 42.

Taking, then, a thickness of 6 feet for the arch-ring, ballasting and roadway, we get 42-6=36 feet as the rise of the arch, and yo is thus 6. Tabulating these data, we have,

$$x_1 = 90 = OX,$$
 (Fig. 1.)
 $y_1 = 42 = bX,$ "
 $y_2 = 6 = Oa,$ "

and we have to find m = OA (Fig. 1) from the formula (1), in which, substituting the numerical values of the signs, we have

$$M = \frac{90}{\text{hyp. log.} \left(\frac{42}{6} + \sqrt{\frac{1764}{36} - \frac{36}{36}}\right)}$$

$$= \frac{90}{\text{(hyp. log. } (7 + 6.9282)}$$

$$= \frac{90}{\text{hyp. log. } 13.9282}$$

The hyp. log. of 13.9282 may be found from the common logarithm, which is 1.143895, in the usual way. It will be found to be 2.6339; substituting this in the equation gives $m = \frac{90}{2.6339} = 34.16$ ft.

Thus, without any previous knowledge of the catenarian curve, the modulus may be found by simply knowing the span of an arch, the height from the springing of the intrados to the roadway, and the depth of arch-ring and loading at the crown, the formula (1) giving the result without difficulty.

So far, however, we have three points only in the intrados, namely, the crown and the two springings; the curve of the arch requires calculating, and this must the fourth column the tabular number

be done by finding the vertical ordinates y, &c., corresponding to their respective abscissae x, &c., which latter may be fixed upon at will.

The formula for calculating the vertical ordinate y for any horizontal distance x from the crown is

$$y = \frac{y_0}{2} \left(e^{\frac{x}{m}} + e^{-\frac{x}{m}} \right)$$
 the quantities $e^{\frac{x}{m}}$

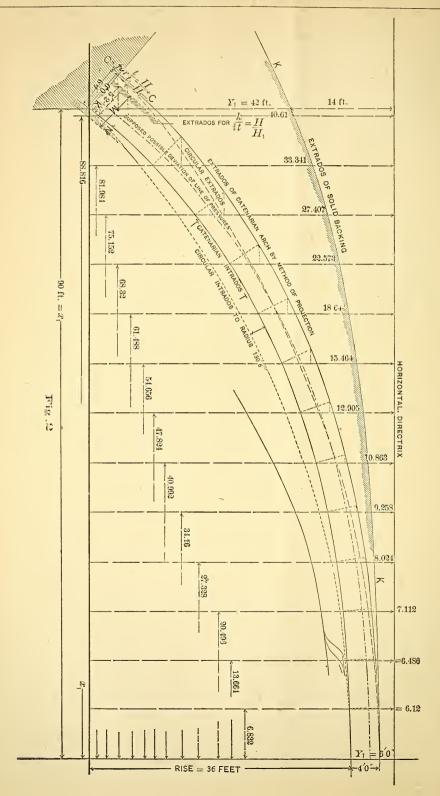
and $e^{-\frac{n}{m}}$ having the values already stated. By fixing certain values to the quantity

 $\frac{x}{m}$ a table may be readily calculated from which the corresponding ordinates y may be found for any catenarian curve whatsoever, thus saving the labor of constantly working out the last equation. Such a table Rankine gives for values of $\frac{x}{m}$ from 0, which corresponds with the vertex to 3.0, beyond which few arches, in stone at least, are found to extend. A similar table, calculated by the writer, is given herewith, extending to $\frac{ic}{in} = 4$

To calculate the vertical ordinates for plotting upon the drawing of the arch (Fig. 2) set down any values of $\frac{x}{x}$ in a column as below.

In the next column from the known value of m=34.16, place the value of x, which set off on the drawing, as shown from the middle ordinate y_a . In the

third column, headed $\frac{y}{y_0}$, place these values as found from Table I., and y, being chosen in this case as 6 feet, set down in



from the third column multiplied by 6. The results will then be the values of the vertical ordinates which are then to be set off on the drawing at their respective distances x from the vertex.

TABLE II. DATA FOR CASE UNDER CONSIDERATION. m=34.16. $y_0=6$

Abscissæ.					Ordinates.
If $\frac{x}{m}$	= .2 the	en <i>x=</i>	=6.832 ar	$\operatorname{ad} \frac{y}{y_0}$	$=1.02 \therefore y=6.12$
44	.4	44	13.664	44	1.081 " 6.486
44	.6	66	20.496	6.6	1.1854" 7.1124
4.6	.8	66	27.328	66	1.3373" 8.0238
6.6	1.0	66	34.16	4.6	1.5431" 9.2586
66	1.2	46	40.992	66	1.8106"10.8636
6.6	1.4	44	47.824	4.6	2.1509"12.9054
66	1.6	. 6	54.656	66	2.5774"15.4644
66	1.8	64	61.488	4.6	3.1074"18.6444
4.4	2.0	6.6	68.32	6.6	3.7622 "22.5732
66	2.2	6.6	75.152	44	4.5679 "27.4074
4.6	2.4	4.6	81.984	44	5.5569"33.3414
4.4	2.6	44	88.816	44	6.769 "40.614
	Half sp	an =	=90.000	4.6	7.000 ''42.000

The correctness of the calculations and plotting is readily judged by the accuracy with which the curve drawn through the points thus formed comes in with the originally chosen ordinate y. at the springing. If the curve does not come in fair it is proof of error in either the plotting or the calculations, which must be corrected.

If we assume that the thickness of the arch stones at the crown is to be 4 feet, there would remain a depth of 2 feet below the directrix or road surface which may be occupied by walling merely. As a matter of fact, in practice such a slight depth as this would require to be wholly solid, as the material for the roadbed would need at least this depth; but the writer purposely chose the dimension Oa (Fig. 1) as only 6 feet, in order that this point in designing might be made clearer, and for a further consideration afterwards to appear. If the whole thickness of crown, 6 feet, was filled solid with masonry, it would be necessary to fill the whole of the spandrills of the arch also solid to the road surface, in order that the weight of every portion of the area aOXb (Fig. 1) might be properly proportioned to the portion of the arch sustaining it; and, therefore, to comply with these conditions, we will assume that the arch crown is solid for a thickness of 4 feet only, the remainder being walled. In order, then, that the the reciprocal = .072.

arch may every where be subjected to the correct loading, we must set off downwards on each ordinate yy, &c., a distance equal to 2 of the distance from the directrix or road surface to the intrados of the arch. A curve KK drawn through the points thus found is then the boundary up to which the solid backing of the arch must be carried, the upper third of the ordinates being, as at the crown, partially filled by a series of walls, upon which rests the roadway, which in the present case we will suppose to be of no weight to suit our otherwise incorrectly chosen dimensions. It may be added here that to correct the fault of too small a thickness at the crown, a higher roadway might have been taken, or a less rise to the arch, so that $O\alpha$ should have been, say, 10 feet. If the roadway had been raised at the crown the extrados of the arch, in place of coinciding with the directrix as now chosen, might have been, as Rankine states, "another transformed catenary having the same directrix." Such, in fact is the extrados of the solid backing in the figure (Fig. 2).

Assuming 120 lbs. per cube foot as the average weight of our arch and load as arranged, $\frac{2}{3}$ solid and $\frac{1}{3}$ in walls and voids, we may calculate the thrust at the crown H, and springing H. These are, by definition, the same as in the catenary of origin, namely, $H=wm^2$.

$$m^2 = 34.16^2 = 1166.9,$$

 \therefore H=140028 lbs.

The thrust along the arch at the springing can only be known when the load P on the half arch is known.

$$P = \frac{wmy_0}{2} \left(\frac{e^{x}}{e^{m}} - e^{-\frac{x}{m}} \right)$$

Now x at the springing = half the span or 90 feet. Therefore

$$P = \frac{120 \times 34.16 \times 6}{2} \left(e^{\frac{x}{m}} - e^{-\frac{x}{m}} \right)$$

$$e^{\frac{x}{m}} = 10^{\frac{34343}{m}}$$
horz. $10 = 1 \cdot e^{\frac{x}{m}} = \frac{90 \times .4343}{34.16} = 1.144$

anti log. of 1.144 = 13.932 and $\frac{1}{13.932}$

$$\therefore \left(e_{m}^{\frac{x}{m}} - e_{m}^{-\frac{x}{m}} \right) (13.932 - .072) = 13.86$$

$$\therefore P = 12297.6 \text{ lbs.} \times 13.86 = 170445.$$

Then the thrust along the arch at the springing

$$=H_1=\sqrt{P^2+H^2}$$

Log. $P^2 = .46316$, &c. $P^2 = 29050$, &c. Log. $H^2 = .292429$, &c. .: $H^2 = 19608$, &c. Sum, 48658, &c.

and
$$\sqrt{48658}$$
, &c. = 220590=H,

Thus $H_1=220590$ pounds compressive $H_1=140028$

strain on each foot of breadth of arch, or 11669 and 18382 lbs. per inch of breadth.

With a factor of safety 10, and assuming 10,000 as crushing strain, the above is equivalent to about 11½ and 18½ inches respectively for depth of arch-ring as a minimum.

The least thickness, according to the empirical formula, usually adopted for keystone dimensions, is $t = \sqrt{.12} R$ and this is greater than the mere crushing If we assume that the arch is circular the radius of the crown R will be with a chord of 180 feet=2x, and a versed sine or rise of 36 feet = v, thus expressed,

$$R = \frac{1}{2} \left(\frac{x^2}{v} + v \right) = 130 \text{ ft. 6 in.}$$

Under this assumption the depth t of the keystone $\sqrt{.12R}$ would be $\sqrt{15.66}$, or 3ft. 10\frac{2}{4}in.—practically 4 feet. ally, however, the crown radius of the catenarian arch is greater than the radius of a circular arch of same span and rise as shown in Fig. 2 where the circular arch is in dotted line.

Taking the catenarian crown radius as we have R=194.5, and t, therefore,

becomes $t=\sqrt{23.34}$, or say 4ft. 10in., being almost exactly five times the calculated strength to resist crushing, and the springing depth on the same assumption must be $18\frac{1}{2}$ in.×5, or 7ft. Sin. To ascertain if the line of pressures falls within the middle third of the thickness of the arch-ring we take $\frac{2}{3}$ of the depth of crown=38 $\frac{2}{3}$ in., and K= $\frac{1}{3}$ the arch thickness at the springing. Then

$$\frac{K}{38\frac{2}{3}} = \frac{\text{Thrust at crown}}{\text{Thrust at springing}}$$
= .6363 ... K=24\frac{1}{2} inches, . (3)

which shows that the depth of arch-ring at the springing must be 6 feet only, and the factor of safety is therefore less than at the crown but still largely in excess. The condition is therefore fulfilled, and the arch stable with these dimensions.*

It is clear, by inspection of Fig. 2, that at the point α a circular arch falls within the true curve, and though this is not apparently the case to an unsafe extent, it appears to show at least a tendency to crush inwards at the haunches. It should not, however, be overlooked that as all arches on settling, after removal of the centerings, come down somewhat at the crown, and that in practice the extreme flatness of the true curve would be well modified, the form of the centerings lying somewhere between the true curve and the circular arc, so that after settlement has taken place the arch may be correct.

It would appear, also, that when the circular form is adhered to, the spandril filling may be lighter than for the ideal arch, so that the flatness about the haunches (at a) may be compensated by a corresponding reduction in the intensity of the pressure, and this may readily be accomplished by the thinning of the walls.

In the case illustrated with the dimensions as purposely chosen to extend this point, the circular arch might, with advantage, have been substituted for the catenary by reason of the fact already pointed out, that the thickness of the arch crown is so nearly equal to the depth yo of the crown ordinate, that, with the arch-ring and the roadway together, the whole depth y_0 would be solid material, and to keep up the conditions of equilibrium the whole spandril filling

$$\frac{t}{t_1} = \frac{H}{H_1}$$
 and $\frac{K}{\frac{2}{3}t} = \frac{H}{H_1}$

^{*} If it is specially desired to adhere to keystone depths exactly proportionate to thrusts along the rib. the value of K might be found as per formula (3) and if it does not come in within the middle third of the thickness of the arch ring, the f curve of the intrados may be modified accordingly. What is necessary under the requirement of the middle third theory is, however, merely that K should exceed a third of the springing thickness and be less than 24 the same.

It will be noticeable also in Fig. 2 that the familiar method of ascertaining the form of extrados by projection of the crown thickness upon the normal gives a thickness of arch ring which falls between the two results obtained by the formula

would require also to be solid up to the horizontal line or directrix. With such dimensions the catenarian form could thus not be strictly adhered to without an unnecessary weight of masonry in the spandril filling. With an exactly equilibrated arch in which an ample depth of keystone has been allowed by the empirical formula already quoted it would seem that the true science of contraction would not demand any solid backing whatever, a mere spandril filling of light wall masonry being alone requisite to carry the horizontal roadway. In Fig. 2 the crown thickness is drawn 4 feet only. The equal strength for the springing will thus be $4 \times \frac{22}{14} = 6.3$ ft., but the formula for K brings out $t_1 = 5$ ft. 2in. only.

To illustrate the transformed catenarian arch under other conditions, let the

dimensions be

Half span=
$$x_1$$
=say, 80 feet,
Rise of arch = "30"

Depth of crown below directrix

$$=16$$
ft. $=y_0$,
=46ft.

Then $y_1 = 30 + 16 = 46$ ft.

Finding the modulus m we have by the formula (1),

hyp.
$$\log \left(\frac{46}{16} + \sqrt{\frac{2116}{256} - \frac{256}{256}}\right)$$

= $\frac{80}{\text{hyp. log. } 5.57} = \frac{80}{1.7174} = 46.58 \text{ ft.}$

Then as in previous example by the use of Table I.,

Assuming an average of 50 lbs. per cubic foot for the whole area of land between the intrados and the roadway, we obtain the thrust at crown $H=vm^2=108484$ lbs. per foot of breadth, or 9040 lbs. per inch of breadth of arch.

The load on half arch per foot of

breadth

$$= P = \frac{mwy_{\circ}}{2} \left(e^{m} - e^{-\frac{x}{m}} \right)$$

 $\frac{x}{m} = 1.717$. Hyp. anti. log. 1.717=5.57.

Recip. 5.57 = .1795 and 5.57 - .1795 = 5.3905

$$P = 18732 \times 5.3905 = 100975.$$

The thrust along arch at springing = H_1 = $\sqrt{P^2 + H^2}$ = 148200 or 12350 lbs. per inch of breadth.

With these stresses at a working stress of 1000 lbs. per square inch, the arch stones would require a depth of 9 inches and $12\frac{1}{2}$ inches at crown and at springing respectively.

The radius at crown is $\frac{m^2}{y_0}$ =135.6 feet, the radius of a similar circular arch being 121.6 ft.

Taking the longest radius, the thickness of crown by empirical rule is

 $t=\sqrt{.12\times135.6}$, or 4 feet, and t_1 at the springing to be equally strong $=4\times\frac{H_1}{H}$ = $5\frac{1}{2}$ feet.

Testing the stability of the arch rin we get

$$\frac{K}{\frac{2}{3} \text{ of } 48} = \frac{H}{H_1} \cdot \cdot \cdot K = 23.3''$$

This number, 23.3, if multiplied by 3 will give 70 inches as the maximum depth of rib at springing. The line of pressure thus falls well within the middle third of the arch-ring at the springing. If 48 inches is considered to be the least thickness of ring at the springing we should find the smallest safe \(\frac{2}{3}\) of the key-

stone depth thus
$$\frac{16}{K} = \frac{H}{H_1}$$
 ... $K = 22$, and

22 is $\frac{2}{3}$ of 33. The keystone depth would be thus not less than 2ft. 9in.

The arch under notice is exceptional as regards the amount of surcharged weight, and the thrust along the arch at the springing is thus not so much in excess of the thrust at the crown, as in the previous example. The first example is by no means uncommon in respect to the thickness of roadbed above the archring. We have already noted that such an arrangement is not correct, theoretically, unless the spandril also is filled solid to the road level; but as the roadbed would be solid only for a short distance, the result would not be serious, though it points to the desirability of

making the curvature somewhat sharper at the crown and flatter at the haunches than the theoretical linear arch.

As an arch with immovable abutments cannot crush inwards at any point without absolute crushing of the material, or bulging outwards of some other part, it would also appear better on this score that the curvature of the crown should be flatter than an absolutely correct arch than that the haunch curvature should be so, because, owing to the greater depth and immobility of the load over the haunches than over the crown, any excess of external load, such as the passage of a heavy locomotive, would, if the curvature of the crown was too sharp, tend, when the load was over the haunches, to cause the crown to rise; and though, again, when the load was over the crown, it would also tend to force this in, it would not so readily do this, because of the difficulty of forcing up the haunches on account of the weight of surcharge, and the variation of the true circle from the catenary at the haunches being in the wrong direction, on the basis of the above hypothesis may be taken as indicative of the necessity of greater consideration being bestowed upon the catenary as a figure for arches.

There is no doubt but that friction plays a most important part as a preserver of arches, especially when subject to heavy passing loads; and vibration is to be avoided as destroying friction. heavy surcharge of earth in preference to or combined with spandril walling would, both as a deadener of vibration and as a means of increasing the ratio of dead to live load, tend to secure stability in an arch.

Between the limits of the two examples we have worked out, possibly fall the majority of stone arches, so far as are concerned depth of loading at crown.

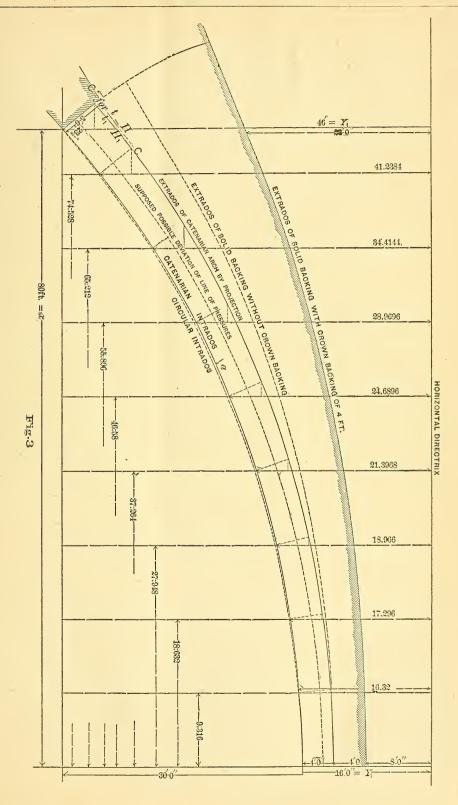
In the Example II. it must be understood that the catenarian curve has been straightway adapted as the actual intra- if the catenary curve can compare, in dos, the limit of the deviation of the linear arch not exceeding $q=\frac{1}{6}$, while in example I., q being above $\frac{1}{6}$ on the basis of considered, however, it is an easy matter

ary, an amount N in this case =6ft. 4in. -5ft. 2in. = 14in., as shown by the short dotted line.*

The largest span of any stone bridge is that of the Washington Aqueduct, a single arch of 220 feet, the next being Harrison's famous bridge over the Dee, Chester, England, 200 feet. these are truly circular, and the Washington arch at the springing is, with its solid backing, as much as 20 feet in thickness. In this way practical men have eliminated the effect of deviations in the line of pressures, for however designed and loaded, it is probable that with the careful bonding of the backing courses, a linear arch can be drawn within what may fairly be called the arch-ring; and looking upon it in this light it appears that, so long as the linear arch falls beyond the intrados, and never within it, i. e., within the archway itself and not through the material of the arch-ring, the arch should be practically safe. The catenarian arch being theoretically designed to be an exact linear rib, it appears almost superfluous to take into consideration the possibility of rupture due to deviation of the line of pressure beyond the middle third of the archring; for, by the very theory of the design, the line of pressure of the whole weight of both the arch-ring and the loading coincides at the intrados with the intrados itself, and at the exterior surface of the solid backing with that exterior surface, if the backing has been correctly proportioned, and it would appear superorogatory to investigate the question of stability on this point, though Rankine, referring to this, says the "resulting curve is simply the curve of the intrados shifted vertically upwards through a height AB," thus apparently hinting that the process is necessary, even to a theoretically proportioned structure.

It may be questioned with some force point of appearance, with the circle as a figure for arches. If appearance is to be

 $[\]frac{t}{t_i} = \frac{H}{H_i}$ the arch-ring, to fulfill this double condition, would require to have been constructed to lie partially on either side of the catenarian curve, the intrados at the springing passing within the caten- [5ft. 2].



to first design the true arch and then so proportion the thickness of the arch-ring that true arch may be contained within an intrados of circular form. It is evident, from Fig. 2, that it is the great weight over the haunches that renders possible the use of the flat crown of the catenarian arch, and opponents of the form may urge that, by properly lightening the haunches of load, the circle may be as mathematically correct as the catenary.

For arches of large spans, however, the catenary curve, presenting, as it does, a direct means of constructing an arch which shall fulfill the conditions of stability if loaded in a manner at which it is easy to arrive, and which presents no difficulties of execution, appears to solve much of the difficulty of the arch question: and it is certain that the headway of a catenarian arch, being greater than that of a circular arch at a little above the springing, tells somewhat in its favor.

The circle may be more eye-pleasing in the opinion of many, but the writer believes that the truer form of the catenary is not displeasing to engineers generally.

In iron structures a notable example of conformity to correct forms is to be seen at Manchester, England, the singlespan roof over the Central Station being constructed of a series of latticed ribs of catenarian form of large span. These concealed by the sidewalls of the station, has not written in vain.

put in chiefly for effect, and the ribs for some height above the springing are stiffened by being solid plated. This structure is a distinct concession to the requirements of ideal form in engineering construction, and worthy of special notice by engineers.

It is noticeable, however, in the arch of Fig. 3 the circle coincides so nearly with the catenarian intrados as to be practically identical with it; but this is not often the case, the depth of crown load being here exceptional. In this respect the catenary bears resemblance to its fellow curve, the hydrostatic, in requiring the designer's attention chiefly when the arch crown approached the directrix, and as at great depths the intrados of a tunnel approximates to the circular form (modified only by the angle of repose of the earth), so does the catenarian arch also approach the true circle. Hence it is easy to see that the stability which practice has shown to be the feature of a deeply-surcharged arch, may not be due altogether to the frictional stability caused by the load, but partially to the coincidence of the actual intrados with the ideal rib.

In conclusion, the writer would add that if what he has written serves in any way to draw attention to the neglect by engineers of true forms, wherewith at ribs spring, in reality, from the ground least to analyze the conditions of their line, though this is to a certain extent actual constructions, he will feel that he

HEAT ACTION OF EXPLOSIVES.*

From "Iron."

The sixth of the course of lectures on "Heat in its Mechanical Applications" was delivered at the Institution, by Captain Andrew Noble, C. B., F. R. S., M. I. C. E. The lecturer commenced by pointing out that the salient peculiarities of some of the best-known explosives might roughly be defined to be the instantaneous—or, at least, the extremely rapid conversion of a solid or fluid into a gaseous mass, occupying a volume many times greater than that of the original body, the phenomenon being generally

* Abstract of a lecture before the Institution of Civil Engineers.

accompanied by a considerable development of measurable heat, which heat played a most important part, not only in the pressure attained, if the reaction took place in a confined space, but in the energy which the explosive was capable of generating. Fulminates of silver and mercury, picrate of potassa, gun-cotton, nitroglycerine and gunpowder, were cited as explosives of this class. The lecturer asserted that substances such as those just named were not the only true explosives. In these solid and liquid explosives, which consisted generally of a substance capable of being burnt, and a

substance capable of supporting combustion, in, for example, gun-cotton or gunpowder, the carbon was associated with the oxygen in an extremely condensed form. But the oxidizable and oxidizing substances might themselves, prior to the reaction, be in the gaseous form; as, for instance, in the case of mixtures of air or oxygen with carbonic oxide, of marsh gas with oxygen, or of hydrogen and oxygen. He added that these bodies did not complete the list, and that, under certain circumstances, many substances ordinarily considered harmless must be included under the head of explosives. making a reference to finely divided substances capable of oxidization, or certain vapors which when suspended in, or diluted with, atmospheric air, formed mixtures which had been the cause of many

serious explosives.

These instances served to show that an explosive might be either solid, liquid, or gaseous, or any combination of these three states of matter. In the first place, a brief account was given of the substances of which some explosives were composed, illustrated by the composition of one or two well-known types. In the second place, the lecturer showed the changes which occurred when explosives were fired, and gave the substances formed, the heat developed, the temperature at which the reaction took place, and the pressure realized, if the products were absolutely confined in a strong enough vessel; relating the experiments which had been made, and the apparatus which had been used, either to ascertain or to verify the facts required by theory, He further supposed all the explosives to be placed in the bore of a gun, and traced their behavior in the bore, their action on the projectile, and on the gun He also described the means and apparatus that had been employed to ascertain the pressure acting on the projectile and on the walls of the gun, and to follow the motion of the projectile in its passage through the bore. He mentioned that the potential energy stored up in a mixture of hydrogen and oxygen forming water was, if taken with reference to its weight, higher than that of any other known mixture, and explained why such an explosive, whose components were so readily obtainable, was not employed as a propelling or disruptive ity varying with the pressure under

agent, the main objection being that if a kilogramme of gunpowder, forming a portion of a charge for a gun, was assumed to occupy a liter or a decimeter cubed, a kilogramme of hydrogen, with the oxygen necessary for its combustion, would at zero and at atmospheric pressure occupy a volume sixteen thousand

times as great.

The lecturer next passed to gun-cotton, described its composition and the various forms in which it was manufactured, referring especially to the forms which were so largely due to Sir Frederick Abel. The various forms of gun-cotton were exploded, and the lecturer remarked on the small quantity of smoke formed, as an indication of the small amount of solid matter in the production of combustion. Also, that instead of the explosions which took place when gaseous mixtures were fired, gun-cotton appeared rather to burn violently than explode. This was due to the ease with which the nascent products escaped into the atmosphere, so that no very high pressure was set up; but it was pointed out that by a small charge of fulminate of mercury, or other means, a high initial pressure was produced, and the harmless ignition shown would be converted into an explosion of the most violent and destruc-This transformation diftive character. fered materially from those which he had hitherto considered. In both of these the elements were, prior to ignition, in the gaseous state, and the energy liberated by the explosion was expressed directly in the form of heat. In the present instance a very large but unknown quantity of heat disappeared in performing the work of bringing the products of explosion to the gaseous state.

Captain Noble then showed that gunpowder, the last and most important example selected, was also by far the most difficult to experiment with, as well as the most complicated and varied in the decomposition which it underwent. One great advantage for the artillerist which gunpowder possessed, in being a mixture, not a definite chemical combination, was that when fired it did not explode in the strict sense of the word. It could not, for example, be detonated as could gun-cotton, or nitro-glycerine, but it deflagated with great rapidity, that rapidwhich the explosion was taking place. As a striking illustration of the effect of pressure in increasing or retarding combustion, he showed an experiment devised by Sir Frederick Abel. It consisted in endeavoring to burn powder in vacuo, and he demonstrated that it would not burn until sufficient pressure was reached. He exhibited the various forms under which gunpowder was manufactured, and ignited some samples of powder, pointing out the essential difference between their combustion and that of gun-cotton, namely the large quantity of what was commonly called smoke slowly diffusing itself in the air. He also exhibited a portion of the socalled smoke of a charge of 15 lb. of powder, collected in a closed vessel.

Captain Noble next described at some length the experiments made with guncotton and gunpowder by Sir. Frederick Abel and himself. With reference to the latter he reiterated their opinion that, except for instructional purposes, but little accurate value could be attached to any attempt to give a general chemical expression to the metamorphosis of a gunpowder of normal composition. further pointed out that heat played the whole rôle in the phenomena. He explained that a portion of this heat, to use the old nomenclature, was latent; it could not be measured by a calorimeter; that was, it had disappeared or been consumed in performing the work of placing a portion of the solid gunpowder in the gaseous condition. A large portion remained in the form of heat, and performed an important part in the action of the gunpowder on a projectile. After describing the apparatus used by Sir Frederick Abel and himself, Captain Noble illustrated the progress that had been made in artillery by mentioning that thirty years ago the largest charge used in any gun was 16 lb. of powder. The 32-pounder gun, which was the principal gun with which the navy was armed, fired only 10 lb.; but he had fired and absolutely retained in one of these vessels, no less a charge than 23 lb. of powder and 5 lb. of gun-cotton.

The lecturer next referred to erosion not one of those who advocated or re-

course were followed, much would be lost and little gained. The bores of guns would be destroyed in a very few rounds. There was no difficulty in making guns to stand pressures much higher than those to which they were normally subjected, but then they must be in a serviceable condition. Nine-tenths of the failures of guns with which he was acquainted had arisen, not from inherent weakness of the guns when in a perfect state, but from their having, from one cause or another, been placed in a condition in which they were deprived of a large portion of their initial strength. He added that, with a given weight of gun, a higher effect could be obtained if the maximum pressure was kept within moderate limits. He stated that the actual pressure reached by the explosion of gun-cotton experimented with by Sir Frederick Abel and himself, assuming the gravimetric density of the charge to be unity, would be between 18,000 and 19,000 atmospheres, or say 120 tons on the square inch. While at the same density, in a closed vessel with ordinary powder, the pressure reached about 6,500 atmospheres, or about 43 tons on the square inch, he had found it possible to measure the pressure due to the explosion of charges at considerably higher density, and had observed pressures of nearly 60 tons with a density of about 1.2.

The lecturer then considered the case of a charge of gunpowder placed in the chamber of a gun; he supposed the gravimetric density of the charge to be unity, that it was fired, and that it was completely exploded before the shot was allowed to move. He exhibited on a diagram a curve indicating the relation between the tension and the density of the products of combustion when employed in the production of work; and observed that in this diagram the tension was represented by the ordinates, the expansions by the abscissas, and the energy developed by any given expansion was denoted by the area between the corresponding ordinates, the curve, and the axis of abscisses. He said that if this theoretic curve was compared with the and its effects, and added that he was curve deduced from experiments in the bores of guns, after the charge might be commended the use of gunpowder giving supposed to be completely consumed, the very high initial tensions. If such a agreement was most remarkable, and afforded ample evidence of the approximate correctness of the theory. He had stated that he could not agree with those who were in favor of the strongestmeaning by the term the most explosive —powder manufactured. To show the advance that had been made by moving in exactly the opposite direction, he exhibited diagrams of two guns of precisely the same weight, but differing in date by an interval of ten years. One of these guns was designed to fire the old-fashioned R. L. G., the other, modern pow-The maximum pressure in the older gun was nearly double that in the modern gun, while the velocity developed by the latter was twice, and the energy not far from three times, that of the former; and if the foot-tons per inch shots' circumference were taken to represent approximately the respective penetrating powers of the projectiles, the superiority of the modern gun would be still more apparent. He directed attention, however, to one point. The new gun was as a thermo-dynamic machine much less efficient than the old. This arose chiefly from the fact that although the new gun was absolutely much longer than its rival, it was, taken in relation to the charge, much shorter; that was, the gases were discharged at the muzzle at a much higher tension.

It remained to consider the total amount of energy stored up in explosives. In the case of the most important —gunpowder—he stated that the total energy stored up was about 340,000 kilogrammeters per kilogram of powder, or, in English measure, a little under 500 foot-tons per lb. of powder. He said that if the potential energy of 1 lb. of gunpowder was compared with that stored up in 1 lb. of coal, his audience being accustomed to the enormous pressures developed by gunpowder, might be somewhat astonished at the results of the comparison. The potential energy of 1 lb. of gunpowder was as nearly as possible $\frac{1}{10}$ of that of 1 lb. of coal, and $\frac{1}{40}$ of that of 1 lb. of hydrogen. It was not even equal to the energy stored up in the carbon which formed one of its own constitueuts. As an economic source of powder was a little under 500 foot-tons level of the lake about 6 in.

per lb. of powder, but it might be desirable to mention what proportion of this theoretic work was realized in modern artillery. He concluded by arguing that, were it necessary to urge the claims of the modern science of thermo-dynamics, he might take, as perhaps the most striking instance, the progress of artillery during the last quarter of a century. Twenty-five years ago our most powerful piece of artillery was a 68-pounder, throwing its projectile with a velocity of 1,600 feet per second. Since then the weight of our guns had been increased from 5 tons to 100 tons, the projectile from 68 lb. to 2,000 lb., the velocities from 1,600 feet to 2,000 feet per second, the energies from 1,100 foot-tons, to over 52,000 foot-tons. Large as these figures were, and astonishing as were the energies which in a small fraction of a second could be impressed on a projectile of nearly a ton weight, they sank into the most absolute insignificance when our projectiles were compared with other projectiles, velocities, and energies existing in nature. Helmholtz had given an estimate of the heat that would be developed if the earth were suddenly brought to rest, but if, looking at the earth in an artillery point of view, and following the principles he had laid down, the earth was considered as an enormous projectile, and if it was supposed further the whole energy stored up in gunpowder could be utilized, there would yet be required a charge 150 times greater than its own weight, or 900 times greater than its volume, to communicate to the earth her orbital motion.

A German mile—about five English miles—contains 25,856 ft.; a square German mile contains therefore 668 million square feet. The superficial area of the Lake of Constance being 8½ German square miles, therefore contains 5682 million square feet. There are living on the surface of the globe at this moment, in round numbers, about 1,430 million human beings. Let every man have 4 square feet allotted to him, and if it were frozen over, the whole human family might find standing room upon the surface of the power, coal had the advantage by at lake. Should the weight prove too great, least two thousand to one. He had stated the ice break, and the whole human race that the total theoretic work of gun- be submerged, it would only raise the

TEMPERATURE OF THE SUN.

BY PROF. DEVOLSON WOOD.

Contributed to Van Nostrand's Engineering Magazine.

In the last March number of this journal is an article by Capt. J. Ericsson, taken from Nature, in which occur the following statements, page 180: "Had Pouillet known that solar radiation, after suffering a two thousand five hundred and seven-fold diffusion, retains a radiant energy of 520° F., he would not have asserted that the temperature of the solar surface is 1760° C. Accepting Newton's law that the temperature is as the density of the rays, the temperature imparted to the heater of the sun motor proves that the temperature of the solar surface cannot be less than $520^{\circ} \times 2507 = 1,303$, 640° Fahr. . . No demonstration whatever has yet been produced tending to prove that the said law is unsound. . . . The temperature produced by radiant heat emanating from incandes-

cent spherical bodies diminishes as the

diffusion of the heat rays."

The law that "the intensity of heat diminishes as the square of the distance from the radiant increases," here referred to as Newton's law, is applicable only to the case where the radiant body is considered as a mere point; and even in those cases the law does not give the temperature of the incandescent body. The law is sufficiently accurate for finite distances from the radiant point, but at the point it gives an infinite temperature in all cases; whereas the radiant, in practice, has only a moderate temperature. To be applicable to the sun it must be considered as a point, instead of a heated surface 400,000 miles from its center. Even if the sun be considered as a uniformly heated mass, the law will not be applicable to it; hence the computation given by Capt. Ericsson gives an erroneous value for the temperature. We know of no way of finding the temperature founded on that method. The heat received by his sun motor emanated from all the points of the solar surface seen from the earth, which will be somewhat less than the surface of a hemisphere of the sun.

Experiment shows that the quantity of heat emanated from an incandescent. body increases more rapidly than the temperature, and that the law deduced by M. M. Pettit and Dulong is given by the equation

 $Q = 1.146 \ fa^t$

Where t is the temperature in degrees centigrade of the hot body, Q=1.0077, f the emissive power of the surface, its superior limit being unity, and r the quantity of heat per square centimeter emitted per minute, being the number of grammes of water raised 1° C. in one minute. Newton's law cannot be substituted for this. Assuming $f = \frac{1}{10}$, Pouillet found the probable temperature of the sun's surface to be 1760° C. A recent determination of the solar constant, by Professor Langley, would, by the same process of analysis, give over 5000° Fahr.

One Rosetti makes the following remark: "The effective temperature of the sun may be defined as that temperature which an incandescent body of the same size placed at the same distance ought to have in order to produce the same thermal effect if it had the maximum emissive power. If we consider the surrounding temperature during the observation to have been 240°, we obtain . . for the effective temperature 9965.4° C. . . I think then I may fairly conclude that the temperature of the sun is not very different from its effective temperature, and that it is not less than 10000° C., nor much more than 20000° C." (Phil. Mag., 1879, Vol. II., p. 548; or American Journal Science and Arts, 1870, II., 68.)

In regard to this result, it appears that the surrounding temperature was assumed too high. Assuming that the temperature measured in the sun's rays is 125° F., and that the atmosphere absorbs 1 the heat, we would have about 156° F. for the intensity of the heat if none were absorbed by the atmosphere,

and this is nearly 70° C., instead of 240°; and taking $\frac{7}{24}$ of the above results gives from 3000° C to 6000° C, nearly; the smaller of which does not differ largely from the corrected value of Pouillet.

One can scarcely conceive of the intense thermal effect produced by a temperature of 5000° F. It is equivalent to melting 16½ miles thick of ice per day on the sun's surface; and each square foot of the surface would require the hourly consumption of more than 1800 pounds of coal to maintain this heat.

The expression, in the above extract, "radiant energy of 520° F.," is unintelligible, since energy is not so measured. Fahr.

The implication that Pouillet did not take into account the diffusion of the rays, is unjust, for that scientist leaves no doubt on that point, as may be seen in his paper on pages 32 and 33 of Comptes Rendus for 1838.

We see no reason for seriously questioning the method of Pouillet. The absorption of the atmosphere varies with the different wave lengths of light, and as measured by Professor Langley ranges from 0.20 to 0.61. Taking the mean as the average absorptive power of the atmosphere, we conclude, according to the method of Pouillet, that the temperature of the solar surface is less than 6000° Fahr.

NOTE ON OPTICAL THEORY OF THE STADIA.

I. O. BAKER, Professor of Civil Engineering, University of Illinois.

Contributed to VAN NOSTRAND'S ENGINEERING MAGAZINE.

In the April number, current year, of this Magazine there appeared an article on the stadia, in which exceptions are taken to the ordinary deduction of the formula for the stadia, but which only confounds wisdom with words, and no understanding. The author of that article was misled by the statement of the text-books, which usually precedes the formula for convex lenses, that "neglecting the thickness of the lens, the formula becomes

$$\frac{1}{p} + \frac{1}{p_1} = \frac{1}{f}$$
."

It is well known that several approximations are involved in the production of the common formula for convex lens; but if any one will take the trouble to follow the effect of these approximations through to the final result, he will find that they nearly neutralize each other. See, for example, Silliman's Physics, pages 321 and 323.

Although the author of that article discovered that his second formula, as above, was not exact, he failed to notice that his first also involved an approximation. He first assumes that the incident and emergent rays intersect in the optical center; this neglects the lateral

In the April number, current year, of is Magazine there appeared an article the stadia, in which exceptions are ken to the ordinary deduction of the rmula for the stadia, but which only infounds wisdom with words, and no displacement of the ray due to its passage through the lens. If the approximations involved in this assumption be also followed through, it will be found that they tend to neutralize the error of the second equation.

The analytical investigation of the effect of the approximations involved in the two fundamental equations, used for the stadia, is too long to be reproduced here, even if it were necessary, besides the writer had no time to attempt it; but having so investigated it, a few years ago, he is prepared to assert that the resulting error in the final formula used for the stadia is wholly inappreciable.

Finally the author of the article in question, seems to think that the errors depend upon the number and form of the componentlenses in the objective. The formula for a convex lens is true for any converging lens or combination of lenses, and the more closely the optical center approaches one face, the more accurate the formula, provided this face is placed toward the cross-hairs, as it should be under any circumstances.

If we wish to compute the coefficient $\frac{f}{i}$ in the stadia formula for the horizontal

distance $D = \frac{f}{i} s + (f+c)$, it is not sufficiently exact to determine f by measuring directly from the lens to the focus for parallel rays; it should be determined by measuring the distance be-tween the object and its image when the two are equal in size and equally distant from the lens, one-fourth of this distance is equal to f, no matter what the form of the lens. If f be determined as above, and i carefully measured, the formula will give results correct to the limits of the accuracy of the observations themselves. The writer made a very satisfactory test of this principle by measuring under a microscope the distance between the threads of an astronomical transit, and computing the equatorial intervals from the value of f determined as above; the actual intervals as determined astronomically, agreed within the limits of the error of the observations.

The writer would not be understood as advocating that $\frac{f}{f}$ should be deter-

mined in this way, but as showing that no appreciable error is involved in the formula D = $\frac{f}{i}s + (f+c)$. Of course, it is better to measure the larger quantities, D and s, and compute the coefficient $\frac{f}{i}$ therefrom. Almost any measurement of f and c is accurate enough for the term (f+c); but if we choose, we may consider both $\frac{f}{i}$ and (f+c) as unknown, when two measures of D and s will give two equations from which $\frac{f}{i}$ and (f+c)may be determined. For greater accuracy, determine several values of each and take the mean.

[Since writing this article, the June number of this Magazine has been received, which contains a surprisingly brief and elegant analytical discussion fully confirming the above.]

DISCHARGE OF STREAMS IN RELATION TO RAINFALL.

BY TIMOTHY AUGUSTINE COGHLAN, Assoc. M. Inst. C. E. From Selected Papers of the Institute of Civil Engineers.

The country watered by the Upper above sea-level, the most noteworthy Nepean, Cordeaux and Cataract rivers, peaks being Mounts Keera and Kembla, comprises an area of 354 square miles, opposite the town of Wollongong. The the mean length from north to south be-average elevation of the basin is probing about 25 miles, while the width from ably not less than 1,200 feet above east to west is on the average 16 miles. It is for the most part uninhabitable, and has been reserved by the Government of New South Wales as the source from which the city of Sydney, with its suburbs, is in future to derive its supply of water. The area included within the tary streams at the head of the rivers. catchment of these rivers lies on the The swamps occur chiefly in the Catawestern side of the range of mountains ract part of the watershed, and though constituting the watershed between the considerable in themselves, do not occu-Nepean Valley and the Illawarra district, py a very large portion of the area. The and is in no place distant more than 20 remainder is a rugged plateau intersected miles from the Pacific Ocean. The ridge by steep and broken ridges, which someforming its eastern boundary is known times rise perpendicularly from the beds as the Illawarra or Mittagong range, and of the streams. The whole country is has an average height of about 2,000 feet barren; the surface-soil is poor, resting

On the eastern side of the the sea. basin, to the lee of the mountains, the country is flat; numerous swamps retain the water, and serve to some slight extent as a storage reservoir, by equalizing the flow and gradually feeding the tribuin many places almost directly on sand-precipitation.

trees attain goodly proportions.

of about 1,400 feet. The rivers, though they rise far apart, converge till the Rain gauges have to Sydney.

Both the Pheasant's-Nest and Broughton's Pass are gorges in the sandstone hills, their sides rising sheer. The fall along the bed of the Nepean is about 70 feet, and of the Cataract nearly 60 feet The rivers near their sources descend from the hills in miniature cascades. The lay of the basin of these rivers is north and east. To this must about 70 square miles, the proportion bebe attributed the equable fall of rain over the basin. The records of a long series of years establish the fact that rainfall over the Nepean area to that of the rain is more copious near the coast the Cataract is as 3.35 to 1. than inland, and that the average depth pends on its distance from the sea.

by the south-east winds, are attributable was in April, 1871, when 0.24 inch, and to the peculiar situation of the adjacent 0.10 inch of rain fell at these places. district forming part of a region of pre-cipitation, of which the Nepean and Cat-aract basin is the extreme south, Long in September and October. Excessive since, the Government Astronomer of falls are often due to great rain-storms New South Wales pointed out that on in the latitudes just beyond the souththe border of the south-east trade, as on east trades. On the 26th of February, that of the north-east, there is a belt of calms, or changeable winds, and that the polar side of this belt is the region of Sydney where a depth of 20 inches has

Port Macquarie, in lat. stone, which crops out on the sides and 32° 47', is usually the limit of the southtops of the spurs of the hills and in the east trade wind on the New South beds of the streams. Vegetation is rep- Wales coast. Then southward for a few resented by stunted varieties of eucalyp- degrees the rainfall is excessive. The tus and epacris, though the scrub is in configuration of the Nepean and Cataract many places thick; in the valleys and basin is, moreover, such as to promote other choice spots the common gum- the discharge of the rain brought by the trade-winds; while, on the other hand, The main branch of the Nepean rises the clouds gathered by the southerly at the extreme south of the watershed winds discharge their moisture on the at a point nearly 2,400 feet above the western or lee side of the coast ridge, level of the sea, whilst the sources of the which has just sufficient elevation to ob-Cordeaux and Cataract have an elevation struct the passage of the clouds and fa-

Rain gauges have been established at Cordeaux unites with the Nepean at the various points in the river basins. The Pheasant's Nest Pass, after a course of values in Table I. are not for one place, about 24 miles, the length of the Nepean but the adjusted means for the whole being about 30 miles. Below the junc- district, giving due weight to the area tion of these rivers a weir was erected to represented by each gauge. The annual gauge their united waters. The Cataract fall of rain varies from 75 inches to 34 approaches the Nepean nearly at right inches. The average fall since 1869 has angles, and at Broughton's Pass, 20 miles been about 54 inches at the Cataract from its source, at the site of a weir, it river, while at the Nepean it has been is only $4\frac{3}{4}$ miles distant from that river. only $44\frac{1}{5}$ inches, or about 82 per cent. of Here a tunnel is being pierced to divert the former. This average holds good part of the Nepean and Cordeaux waters both for a series of months and years, to the Cataract, to be thence conducted the excess on the Cataract basin being attributable to its closer proximity to the sea, the dividing ridge being there only 3 miles distant from the Pacific Ocean, and also to its trending towards the direction from which the heaviest downpour comes. Table I. shows the proportion of water falling on the two basins.

The area of the Nepean basin is about 284 square miles, and of the Cataract ing as 4.06 to 1. The average rainfall is 0.825 to one; thus the proportion of

The heaviest rain observed during any of rain at a particular place generally demonth was in February, 1873, when 22.43 inches fell on the Cataract, and 19.78 At Sydney the heavy rainfalls, brought inches on the Nepean basin; the least

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fallen in 24 hours. The average number of rainy days for the year is one hundred and forty; the number of days of continuous rain has been twenty-six, and periods of seven days continuous rain are not unfrequent. Droughts are, unfortunately, also of long duration; thus, from July, 1875, to April, 1876, a period of two hundred and eighty-seven days, the total depth of water falling on the Nepean basin was only 14.93 inches, and from February to October, 1872, being two hundred and thirty-five days, only 10.43 inches fell. The longest time without rain was about twenty days.

The annual evaporation varies from 70 to 30 inches, the mean being 48 inches. These figures are somewhat in excess, as the circumstances under which measurements to ascertain evaporation are made bear little analogy to that of water from lakes, swamps or streams. Bearing this in mind, the annual evaporation from water exposed to the direct effect of the sun may be taken as about 36 inches. But in a country covered with thick scrub, as here, evaporation from the ground is not so considerable as is sometimes supposed. Rain is effective, not so much in direct proportion to the volume falling as according to the distribution of that volume. For instance, at the Cataract river 75 inches in 1873 producd less discharge than 64 inches in 1870; again, 54 inches, which fell in each of the years 1871 and 1874, gave rise to almost the same discharge, while a similar depth of rain in 1875 produced much less flow. In regard to the exceptional discharge of 1870, in the months during which the greater part of the rain fell, it rained nearly every day; the ground was saturated, and the water ran off in streams before evaporation and soakage could take place. During 1874 the discharge was high; the previous year had been wet, particularly in the latter months, and in the first six months of 1874 a considerable depth of rain also fell, the latter half year being dry. In 1875, though the first period of the year was wet, the previous months of 1874 had been dry, and the rain was for that reason not effective.

With regard to the ultimate destination of the rain, assuming 44 per cent. to pass off by streams, as will hereafter appear, the depth of water annually evaporated is 36 inches out of a rainfall of taken, and the velocities measured at the

54 inches, or 66 per cent. This would be, of course, impossible, in view of the volume yielded to the streams; but there are many causes operating to diminish evaporation, by preventing the direct action of the sun, so that in all likelihood the water re-evaporated does not amount, on the average, to much more than 33 per cent. of the rain, the remainder, after deducting the stream discharges, escaping underground. No rule can be laid down in regard to this matter, as the possible evaporation is always greatest when the rain is least, the maximum rainfall being accompanied by the minimum of evaporation. The observations seem to indicate that in years of abundant rain, not more than 15 per cent. of the rain is re-evaporated, the remainder going to feed the streams or being absorbed by the soil. In years of low rainfall the amount of evaporation is from 50 to 60 per cent., while during average years 33 per cent. would represent the rain thus lost. Regarding the disposal of rain underground, part is returned to the rivers by springs through crevices in the rocks, part is absorbed by vegetation, and part is carried away through fissures in the rocks or breaks in the strata to places below the streams. Tunnels and openings in the Sydney sandstone show that waste from this last source is considerable.

Convenient points were chosen for the erection of the weirs, the rivers being dammed by planks of Oregon pine, 21 inches thick, bolted to the rock in the bed of the river and calked with oakum. The notch at the Cataract was 3 feet 6 inches, and at the Nepean 10 feet wide, both being 1 foot deep. The formula given by Rankine,

$Q = 5.35 c b h \frac{3}{2}$

was used in calculating the discharge when the water falling over the wier was less than 1 foot deep, c being considered as 0.598; thus the formula reads

Q=b h = cubic feet per second.

When the water rose over the top of the notch to a moderate height, the discharge was taken as that of a drowned weir. Elaborate observations were made to ascertain the discharge of the rivers when in flood; various cross sections were

cross section were compared. The inclinations of the rivers were also recorded at suitable points, the probable discharges calculated therefrom, and the new results compared with the former ones and with one another, and in this way a table of the probable discharge at each foot in height was arrived at. results hereafter stated may be considered fair approximations of the discharges of the rivers.

Gaugings were commenced towards the close of the year 1868, and they are From this period of still carried on. upwards of fourteen years, during the interval from July, 1869, to June, 1876, which has been selected as containing illustrations of all the circumstances that need remark, the average annual depth of rain was 53.99 inches on the Cataract basin, and 44.28 inches on that of the Nepean, the proportion being as 1 to 0.823; but as the area of the basin of the former river was hardly one quarter of the latter $(\frac{70}{284})$, the proportion of rain falling on each district was as 1 to 3.34. The average yearly discharges were 24,-484,000,000, and 80,383,000,000 gallons, equivalent to 24.14 and 19.54 inches of rainfall respectively, or, allowing for the superior area of the Nepean, as 1 to 3.28.

The records of rainfall and disharge for any particular year show that the dry years are somewhat in favor of the smaller area, while the wet years give either corresponding results, or are in favor of the Nepean. It has been usual to assume that the proportions would be in favor of the smaller area, this proportion being reckoned as a to A_3 , where a=discharge per unit of the smaller, and A that for the larger area. The observations taken at the Nepean and Cataract rivers, on the contrary, indicate that the total flow of water from similar districts is in proportion to the volume of the rainfall and the area of each district, bearing in mind always that there is no great disparity in the two areas. proportion between rainfall and discharge is, in the case of the Cataract, 44.7 per cent., while in the Nepean it is 44.1 per cent. for an extended period, including every condition of flood and drought. This is a much larger proportion than is generally reckoned on; but, if there be

different flood heights when opportuniany error, it is on the side of being short ties offered, and the results for each of the full quantity, owing to the rapidity with which freshets rise in districts of heavy rainfall, and the difficulty of The average measuring their volume. of freshets is about 54 per cent. of the rainfall, while, after the ground has become saturated with previous rain, the volume discharged is nearly equal to the quantity of rain falling. In dry seasons the volume of the streams bears but a small proportion to the depth of rain, from 10 to 12 per cent. being the average yield. The tables show various comparisons between the two streams in regard to the rainfall and the flow due to that rainfall, from which it is evident that their discharges, notwithstanding the difference in drainage areas, is in proportion to the rainfall, the dry periods being decidedly in favor of the smaller area; but the quantity of rainfall and water carried off by the streams in droughts is so small that when the whole is comprised the discrepancy is not shown.

Rejecting the incomplete years 1869 and 1876, it will be seen in the Nepean River, when arranged (a) according to the rainfall, (b) the discharge, and (c) the proportion of rain discharged (the years giving the largest results being placed first on the list), that for the Nepean River the years come in the order shown in The result of the grouping Table II. shows that the greatest rainfall is attended by the greatest discharge, and also by the greatest proportion of discharge to rainfall; and not only so, but the years follow in every case in their proper order. Of course this cannot be looked upon as other than a coincidence, remarkable certainly, but still only a coincidence. Turning now to the Cataract, the years in the same way are as shown in Table This is satisfactory, except in respect to 1873, which was a year of abundant rain, though the flow was not proportionate to the rain. The deduction to be derived from this and the preceding Table is obvious. The quantity of water carried off by a stream is not directly proportional to the rainfall; but the greater the quantity of rain falling within a given time, the greater is the percentage of that rain carried off by the streams.

In rainy periods the greatest floods,

TABLE I.—SHOWING PROPORTION OF RAINFALL DISCHARGED BY EACH RIVER.

Year.	Rain	fall.	Discharges in Inches of Rain. Per Centage of Rain Discharged.		Proportion of Nepean Rain to	Proportion of Nepean Discharge		
	Cataract.	Nepean.	Cataract.	Nepean.	Cataract.	Nepean.	Cataract Rain.	to Cataract Discharge.
1869 1870 1871 1872 1873 1874 1875 1876	14.35 64.16 53.70 40.23 75 08 54.38 54.36 21.30	12.77 64.01 43.36 34.37 57.49 42.50 41.28 16.06	4.48 43.30 26.54 10.53 32.58 27.33 20.42 4.84	1.82 43.66 21.23 6.85 28.40 17.30 13.79 1.44	31.22 67.48 49.42 26.17 43.38 50.25 37.6 22.74	14.3 68.20 49.00 19.93 49.40 40.70 33.40 9.00	89.00 99.70 80.8 85.4 76.98 78.15 75.9 75.4	40.8* 100.8 80.0 65.0 88.71 63.30 67.5 29.75*
Average	53.99	44.28	24.14	19.54	44.70	44.10	82.00	81.00

^{*} Six months.

TABLE II.—NEPEAN RIVER. TABLE III.—CATARACT RIVER. (b) Discharge. (c) Proportion of Rainfall to (c) Proportion (a) Rainfall. (b) Discharge. of Rainfall to (a) Rainfall. Discharge. Discharge. 1870 1870 1870 1873 1870 1870 1873 1873 1873 1870 1873 1874 1871 1871 1874* 1874 1871 1871 1874 1874 1874 1875* 1871 1873 1875 18751875 1871* 1875 1875 1872 1872 1872 1872 1872 1872

not only actually, but proportionately to stance, on the 23d of February, 1873, the area of basin, were experienced first in the Nepean, notwithstanding its area was four times as large as that of the adjacent stream, though during the whole time of flood almost similar proportions of the rain were measured as given off by the two streams. This may be accounted for by the existence of large swamps in the Cataract district, which act as flood moderators, whereas in the Nepean very little of the rain is retained by the swamps; to this fact, likewise, must be attributed better results from the dryweather discharge of the Cataract.

Experience elsewhere has led to the conclusion that flood volumes are proportionately greater for smaller areas, and formulas have been constructed on this basis; but the experience derived from streams in New South Wales does not favor this assumption, though it may be correct in the main. The great floods of

Nepean flowed 1.20 foot over the sill of the weir, on the 24th 4.15 feet, on the 25th about the same, but on the 26th a depth of 55 feet of water was measured at eleven o'clock, and of 60 feet later in the day; twenty-four hours afterwards the depth was 30 feet; on the 28th the river ran 10 feet deep, gradually falling to 4 feet five days afterwards. The quantity passing down during the height of the flood in twenty-four hours was probably 30,000,-000,000 gallons, which would make the coefficient c in the formula,

$$\Phi - c \times 27 \text{ (M)} \frac{1}{2}$$

equal to 120, instead of 28, as usually adopted.

By Fanning's formula, where

$$\Phi = 200 \text{ (M)} \frac{5}{6}$$

 Φ =cubic feet per second, and M=area of watershed in miles, the result is about 12,the Nepean rise 60 feet, but remain at 000,000,000 against 30,000,000,000 gals., that height only a short time; for in-asabove stated. This was an extraordinary

^{*} Nearly equal.

instance, floods in general being not inch per day. more than 40 feet over the sill, giving a daily discharge at the top of the flood of about 18,090,000,000 gallons, a quantity much beyond the scope of the formula.

The Nepean River, therefore, hardly comes within the limits contemplated by the authors of these formulas, though in the Cataract there is a nearer approach to the result derived from the formula. In the latter stream the flood rises 24 feet, and discharges a volume in twentyfour hours of 3,787,000,000 gallons, while the formula of Fanning gives 3,768,000,-

000 gallons.

No attempt is here made to bring flood volumes within the bounds of a rigid mathematical formula, there being no agreement between the two rivers to admit of such, especially as the principle, that the floods of the larger area are proportionately less than those of the smaller, would be violated. But though in isolated floods no agreement is observable, yet in the general results of large and small flows, as compared with the rainfall, there is ample evidence of the operation of fixed laws.

From the 28th of August 1869, when both streams were low, till the first of May, 1876, the end of a long continued drought, a succession of freshets occurred over periods of time varying from three hundred and six to fourteen days, alternating with intervals of small flow, the longest of which was 287 days. The total quantity of rain causing floods or freshets during these periods was, in the Cataract River, about 290.98 inches, of which 153.86 inches, or about 53 per cent., flowed over the sill of the weir. In the Nepean basin 239.87 inches fell, and 124.17 inches, or 52 per cent., of this quantity passed down the stream, the percentage being nearly the same in each The largest ratio of flow to rainfall in the Cataract was nearly 70 per cent., the least for any considerable time was 26.6 per cent. In the Nepean the largest proportion was 67.76 per cent., the lowest 23.6 per cent. The total time occupied by freshets was eleven hundred and sixty-two days, and that reckoned as ordinary flow was eleven hundred and one days. The average rainfall for the Cataract during freshets was 0.25 inch per day, the quantity carried off giving an equivalent of 0.133 flow, whereas in the case of low discharges

At the Nepean the average rain amounted to 0.207 inch, the greatest discharge being equivalent to a little more than 0.107 inch. author's measurements show that during freshets the proportion of water carried off by a stream is greater or less according as the time during which the freshets last is longer or shorter, other things being equal. This law is apparent in the whole series from 1868 to the present time.

The formula, used by the author for the calculation of the quantity of water due to freshets from natural drainage districts of moderate size, is an empirical one, but can be relied on fairly well

within certain limits; it is

$P = t c R^{1.9}$.

Where P = inches of rainfall discharged by streams.

> t = coefficient for time, the valueof which is governed by the length of time the freshets last.

> c = coefficient of rainfall varying with the quantity of rain.

R = average daily rainfall in inches during freshet.

Not less important than the observation of streams in flood is the determination of their ordinary flow; in fact the latter is of greater moment to an engineer seeking for an efficient water supply. For the eleven hundred and one days of ordinary flow, the rainfall was 73.74 inches at the Cateract, and 59.42 at the Nepean river, being an average daily fall of 0.070 and 0.055 inch. The rain yielded a gross equivalent flow of 8.73 and 5.90 inches, or a percentage of 11.8 in the one case, and of 10.0 in the other. Statements of the different low discharges are arranged in the order of occurrence in Tables IV. and V. Both these tables are to some extent inconsistent. cause lies in the difficulty of determining the exact time when a dry period begins. No matter how low the water may be in the streams, there is always some water due to the wet period preceding the dry This cause of error also operates in rainy weather, but not to a serious extent, as the water due to previous rain forms but a small portion of the whole

TABLE IV .- CATARACT RIVER.

Length of Low	Rair	nfall.	Discharge.		
Discharge.	Total.	Per Day.	Equivalent of Rain	Proportion to total rain	
190 days. 194 '' 162 '' 34 '' 17 '' 13 '' 54 '' 20 '' 147 '' 287 ''	15 44 inches. 14.72 " 6.60 " 1.60 " 0.27 " 0.26 " 3.28 " 2.07 " 8.73 " 20.67 "	0.081 inch. 0.076 '' 0.040 '' 0.048 '' 0.016 '' 0.020 '' 0.060 '' 0.104 '' 0.059 '' 0.090 ''	2.72 inches. 1.78 " 0.80 " 0.17 " 0.14 " 0.13 " 0.67 " 0.23 " 1.01 " 1.08 "	17.6 per cent. 12.1 " 12.1 " 10.6 " 51.9 " 36.1 " 20.4 " 11.1 " 11.6 " 5.2 "	

TABLE V.—NEPEAN RIVER.

Length of Low	Rair	fall.	Discharge.		
Discharge.	Total.	Per Day.	Equivalent of Rain.	Proportion to total rain	
190 days. 194 '' 162 '' 34 '' 17 '' 13 '' 20 '' 147 '' 287 ''	14.74 inches. 10.63 " 5.21 " 1.93 " 0.23 " 0.38 " 2.38 " 1.42 " 7.67 " 14.93 "	0.077 inch. 0.055 '' 0.032 '' 0.057 '' 0.013 '' 0.030 '' 0.061 '' 0.061 '' 0.052 '' 0.052 ''	1.61 inch. 1.18 " 0.55 " 0.19 " 0.08 " 0.09 " 0.38 " 0.11 " 0.68 " 1.04 "	11.1 per cent. 11.1 " 10.4 " 9.8 " 34.8 " 23.7 " 12.3 " 9.7 " 8 9 " 7.0 "	

the extent of 50 per cent. The practice followed by the author is to count as available only 10 per cent. of the rainfall for periods of small flow up to one hundred fifty days; for the succeeding fifty days the amount taken is 8 per cent.; for the following fifty days, 6 per cent., and for the next fifty days, 4 per cent. This gives three hundred days in a period of exceptional drought. The above is less than the practice genereally obtainfrequently great heat of the dry sum-laid down as to relative discharges. mers. During the drought in 1875-76, which lasted for more nine months, the discharge at the Nepean river in the first half of the period, after deducting the was only equal to 4 per cent.

this item may be a factor sometimes to Cataract during the time yielded a still smaller percentage.

The conclusion to be drawn from the gauging in season of small flow is, that for periods of like rainfall the discharge of the streams is greater or less, accordas the time over which the rainfall extends is or less greater. This general rule is subject to modification from various causes, the chief being the extent of evaporation, and the volume of rainfatl within short periods, such exceptions ing elsewhere, but it is warranted by the not invalidating the general principles

Regarding the economical size of the channel to deliver water from streams to a storage at some distanca, it is difficult to define exact rules, as the useful diswater due to previous rainfall, was equal charge depends greatly upon the equable to about 9 per cent. of the rain; whilst distribution of the rain throughout the during the latter part of the discharge year, and on the retention of large quan-The tities of water in swamps, sand-drifts, or such like natural reservoirs, until delivred to the streams, when they begin to fall off in volume.

Perhaps as good an example of natural storage as could be found is afforded by the Botany and Lachlan swamps, whence the city of Sydney at present draws its supply of water. The swamps and sanddrifts now comprise an area of about 8 square miles, though for years the area supplying Sydney was not more than $5\frac{3}{4}$ miles. From the latter area a supply of water has been drawn equal to about 18 inches of rain, while the total depth of rain on the average is not much more than two-and-a-half times that quantity. From the 1st of January to the 8th of April, 1876, the latter portion of the drought, during which scarcely 12 inches of rain fell in nine months, and only 4.10 inches in the above-named period, the water in the swamps was carefully gauged, and it was ascertained that the amount drawn off for consumption was about 400,000,000 gallons; the volume of water by evaporation in excess of rainfall may be taken at 116,000,000, whilst the quantity available within the dams at the end of the period was 51,000,000 gallons, giving a total of 567,000,000 gallons used or available for use during period. Against this quantity is to be set the water in the various reservoirs upon the 1st of January, 1876, which amounted to 173,000,000 gallons, leaving 394,000,000 gallons unaccounted for. This represents an equivalent of about 7 inches of rain over the whole available Botany portion, comprising an area of 4 square miles. It was drawn entirely from the sand, and as the water-levels on the inner side of the dams were reduced, the water pouring in from the sand increased in volume, so that in April the discharge was 500,000 gallons per day more than at the beginning of the year, whilst the rainfall was so small as to be negligible.

In the Nepean and Cataract rivers an equable flow depends almost entirely upon the distribution of the rain; thus at the Cataract, 75 inches of rain in 1873 were of very little more value for water-supply than 54 inches in the following year. This was owing to the rainfall in 1874 having been better distributed than

in the previous year.

If the average daily volume of a the formula becomes

stream be taken as a standard, and a channel be assumed as capable of carrying off the whole of this quantity, provided the stream was of the same dimension each day, the actual discharge of such a channel would be about 41 per cent. of the whole discharge of the stream, the remaining 59 per cent. not being available from the floods bringing down a far greater body of water than the channel could carry off, even though its capacity were equal to the mean discharge. If the capacity of the channel were one half the mean daily discharge, it would convey 26 per cent. of the total A channel equal to ouedischarge. fourth of the mean daily flow would carry off nearly 17 per cent. of that quantity; while a channel, with a capacity equal to one-eighth the mean discharge, would convey 10 per cent., and one equal to one-twentieth would yield very nearly 5 per cent., or about as much as its maximum discharge.

The formula used by the author in establishing the economical size of chan-

$$\Phi = \left(\frac{R}{12} \times \frac{D}{4}\right)$$

where Φ = the equivalent in inches of rain that would be carried down by a channel equal to the mean daily discharge of the stream; R = the rainfall during any year, and D=the discharge for such year in inches of rain. For any channel of less capacity than the average daily discharge, the formula becomes

$$\Phi = c \left(\frac{R}{12} + \frac{D}{4} \right),$$

where Φ =quantity conveyed by channels of various sizes, c being the coefficient varying with the size of channel. The value of c for a conduit equal to the daily average of the stream feeding the conduit is 1.00. Table VI.

TABLE VI.

Where the proportion between R and D is known, be is frequently the case, the formula becomes

$$\Phi = \frac{c(1+3n) R}{12},$$

where n R=discharge D; Φ and R as above; c being the coefficient varying with the size of the conduit.

The interval to which direct reference is made in this paper only extends from 1869 to 1876; but the whole period during which gaugings have been taken has been used for correcting formulas, or for the purpose of comparison, the mean results for the restricted period use in similar circumstances elsewhere.

agreeing with those the whole period from 1869 to the dresent time.

The formulas and conclusions are intended in the first place to illustrate the conditions of flow in small mountain streams in Few South Wales; but the circumstances connected with the Australian climate are not, as is often assumed, very different from those which obtain in other parts of the world, and it is therefore probable that the experience acquired in New South Wales may be of

THEORY OF MAGNETISM.*

By PROF. D. E. HUGHES, F. R. S.

From "English Mechanic and World of Science,"

The theory of magnetism, which I propose demonstrating this evening, may be termed the mechanical theory of magnetism, and, like the now well-established mechanical theory of heat, replaces the assumed magnetic fluids and elementary electric currents by a simple, symmetrical mechanical motion of the molecules of matter and ether.

That magnetism is of a molecular nature has long been accepted, for it is evident that, no matter how much we divide a magnet, we still have its two poles in each separate portion; consequently we can easily imagine this division carried so far that we should at last arrive at the molecule itself possessing its two distinctive poles; consequently, all theories of magnetism attempt some explanation of the cause of this molecular polarity, and the reason for apparent neutrality in a mass of iron.

The influence of mechanical vibrations and stress upon iron in facilitating or discharging its magnetism, as proved by Matteucci, 1847, in addition to the discovery by Page, 1837, of a molecular movement taking place in iron during its magnetization, producing audible sounds, and the discovery by Dr. Joule, 1842, of the elongation of iron when magnetized, followed by the discoveries of Guillemin, that an iron bar bent by a weight at its extremity would become straight when

magnetized; also that magnetism would tend to take off twists or mechanical strains of all kinds—together with the researches of Matteucci, Mariana, De la Rive, Sir W. Grove, Faraday, Weber, Wiedemann, Du Moncel, and a host of experimenters, including numerous published researches by myself—all tend to show that a mechanical action takes place whenever a bar of iron is magnetized, and that the combined researches demonstrate that the movement is that of molecular rotation.

De la Rive was the first to perceive this, and his theory, like those of Weber, Wiedemann, Maxwell, and others, is based upon molecular rotation. Their theories, however, were made upon insufficient data, and have proved to be wrong as to the assumed state of neutrality, and right only where the experimental data clearly demonstrated rotation.

I believe that a true theory of magnetism should admit of complete demonstration, that it should present no anomalies, and that all the known effects should at once be explained by it.

From numerous researches I have gradually formed a theory of magnetism entirely based upon experimental results, and these have led me to the following conclusions:

1. That each molecule of a piece of iron, as well as the atoms of all matter, solid, liquid, gaseous, and the ether itself, is a separate and independent mag-

 $[\]ensuremath{^{*}}\xspace$ A lecture delivered before the Royal Institution, slightly condensed.

net, having its two poles and distribution of magnetic polarity exactly the same as its total evident magnetism when noticed

upon a steel bar-magnet.

2. That each molecule, or its polarity, can be rotated in either direction upon its axis by torsion, stress, or by physical forces such as magnetism and electric-

3. That the inherent polarity or magnetism of each molecule is a constant quantity like gravity; that it can neither

be augmented nor destroyed.

- 4. That when we have external neutrality, or no apparent magnetism, the molecules or their polarities arrange themselves so as to satisfy their mutual attraction by the shortest path, and thus form a complete closed circuit of attraction.
- 5. That when magnetism becomes evident, the molecules or their polarities have all rotated symmetrically, producing a north pole if rotated in a given direction, or a south pole if rotated in the opposite direction. Also, that in evident magnetism we have still a symmetrical arrangement, but one whose circles of attraction are not completed except through an external armature joining both poles.

6. That we have permanent magnetism when the molecular rigidity—as in tempered steel—retains them in a given direction, and transient magnetism whenever the molecules rotate in comparative

freedom—as in soft iron.

EXPERIMENTAL EVIDENCES.

In the above theory the coercive force of Poisson is replaced by molecular rigidity and freedom; and as the effect of mechanical vibration, torsion and stress upon the apparent destruction and facilitation of magnetism is well known, I will, before demonstrating the more serious parts of the theory, make a few experiments to prove that molecular rigidity fulfills all the requirements of an assumed coercive force.

I will now show you that if I magnetize a soft iron rod the slightest mechanical vibration reduces it to zero; whilst in tempered steel or hard iron the molecules are comparatively rigid, and are but slightly affected. The numerous experimental evidences which I shall show

completely rigid in steel, they are comparatively rigid when compared with the extraordinary molecular freedom shown in soft iron. (Experiments shown.)

If I now take a bottle of iron filings, I am enabled to show how completely rigid they appear if not shaken; but the slightest motion allows these filings to rotate and short-circuit themselves, thus producing apparent neutrality. will restore the lost magnetism by letting the filings slowly fall on each other under the influence of the earth's magnetic force; and here we have an evident proof of rotation producing the result, as we can ourselves perceive the arrangement of the filings. (Experiment shown.)

If I take this extremely soft bar of iron, you notice that the slightest mechanical tremorallows molecular rotation, and consequent loss or change of polarity; but if I put a slight strain on this bar, so as to fasten each molecule, they cannot turn with the same freedom as before, and they now retain their symmetrical polarity like tempered steel, even when violently hammered. (Experiment

We can only arrive at one conclusion from this experiment, viz., that the retention of apparent magnetism is simply due to a frictional resistance to rotation; and whenever this frictional resistance is reduced, as when we take off a mechanical strain, or by making the bar red hot, the molecules then rotate with an almost inconceivable freedom from frictional resistance.

CONDUCTION.

You notice that if I place this small magnet at several inches' distance from the needle it turns in accordance with the pole presented. How is the influence transmitted from the magnet to the needle? It is through the atmosphere and the ether, which is the intervening medium. I have made a long series of researches on the subject, involving new experimental methods, the results of which are not yet published. One result, however, I may mention. We know that iron cannot be magnetized beyond a certain maximum, which we call its saturation point. It has a well-defined curve of rise to saturation, agreeing completely with a curve of force produced by the prove that whilst the molecules are not rotation of a bar magnet, the force of

which was observed from a fixed point. I have completely demonstrated by means of my magnetic balance that our atmosphere, as well as Crooke's vacuum, has its saturating point exactly similar in every respect to that of iron: it has the same form through every degree. We cannot reduce or augment the saturating point of ether; it is invariable, and equals the finest iron. We may, however, easily reduce that of iron by introducing frictional resistance to the free motion of its molecules.

From consideration of the ether having its saturating point, I am forced to the conclusion that it could only be explained by a similar rotation of its atoms as demonstrable in iron.

Reflection would teach us that there cannot be two laws of magnetism, such as one of vibrations in the ether and rotations in iron. We cannot have two correct theories of heat, light, or magnetism; the mode of motion in the case of magnetism being rotation, and not vibration.

Let us observe this saturation point of ether compared with iron. I pass a strong current of electricity in this coil. The coil is quite hot, so we are very near its saturation. I now place this coil at a certain distance from the needle (Sin.); we have now a deflection of 45° on the needle. I now introduce this iron core, exactly fitting the interior previously filled by the ether and atmosphere. force is much greater, so I gradually remove this coil to a distance, where I find the same deflection as before (45°). This happens to be at twice the distance, or 16in., so we know, according to the law of inverse squares, that the iron has four times the magnetic power of the ether. But this is only true for this piece of iron; with extremely fine specimens of iron I have been enabled to increase the force of the coil forty times, whilst with manganese steel containing 10 per cent. of manganese it was only 30 per cent. superior. We see here that the atmosphere is extremely magnetic. Let us replace the solid bar by iron filings. We now only have twice the force of ether. Replace this by a bottle of sulphate of iron in a liquid state: it is now a mere fraction superior to the atmosphere; and if we were still further to separate the iron reasonable to suppose that if we could isolate the iron gas from that of ether, that iron gas would be strongly diamagnetic, or have far less capacity than ether, owing to the great separation of its molecules. These are assumptions, but they are based upon experimental evidences which gives the related to the second of th

ences, which give them value.

Let us quit the domain of assumption to enter that of demonstration. Here I have a long bar of neutral iron. place this small magnet at one end, we notice that its pole has moved forward 3in., having a consequent point at that place. Let us now vibrate this rod, and you notice the slow but gradual creeping of the conduction until at the end of two seconds it has reached 14in. The molecules have been freed from frictional resistance by the mechanical vibrations, and have at once rotated all along the Let us repeat this experiment by heating the rod to red heat. You notice the gradual creeping or increased conduction as the heat allows greater molecular freedom. Let us now again repeat this experiment by sending a current of electricity through the bar. You notice the instant I touch the bar with this wire, conveying the current through it, that we have identically the same creeping forwards, no matter what direction of the current. If you simply looked at the effects produced, you could not tell which method I had employed; either mechanical vibrations, heat vibrations, or electrical currents. Consequently, knowing the two first to be modes of motion, it is fair to assume that an electrical current is a mode of motion, the manner of which is at present unknown; but that there is a molecular disturbance in each case is evident from the experiments shown.

NEUTRALITY.

force of the coil forty times, whilst with manganese steel containing 10 per cent. of manganese it was only 30 per cent. superior. We see here that the atmosphere is extremely magnetic. Let us replace the solid bar by iron filings. We now only have twice the force of ether. Replace this by a bottle of sulphate of iron in a liquid state: it is now a mere fraction superior to the atmosphere; and if we were still further to separate the iron molecules, as in a gaseous state, it is

become mixed in each molecule, thus neutralizing each other. Ampere supposes that the elementary currents surrounding each molecule have become heterogeneous. De la Rive, Wiedemann, Weber, Maxwell, and all up to the present time have accounted for this disappearance as a case of mixture of polarities

or heterogeneous arrangement.

My researches proved to me that neutrality was a symmetrical arrangement; I stated this in my paper upon the theory of magnetism to the Royal Society last year. I have since made a long series of researches upon this question, which demonstrate beyond question—1. That a bar of iron under the influence of a current or other magnetizing force is more strongly polarized on the outside than in the interior; that its degree of penetration follows the well-defined law of inverse squares up to the saturation point of each successive layer. 2. The instant that the current ceases a reaction takes place, the stronger outside reacting upon the weaker inside, completely reversing it, until its reversed polarity exactly balances the external layers.

We might here suppose that there existed two distinct polarities at the same end of a neutral bar, but this is only partially true, as the rotation of the molecules from the inside to the exterior is a gradual, well-defined curve, perfectly marked. In a large solid bar the reversed polarity would be in the interior; but in a thin bar, under an intense field, the reversed polarity would be on the outside. Thus, a bar which had previously strong north polarity under an external influence would, the instant it formed its neutrality, have a north polarity in the interior covered or rendered neutral by an equal south exterior, the sum of both giving the apparent neutrality that we notice.

If I take this piece of soft steel and magnetize it strongly it has a strong remaining magnetism, or only partial neutrality. If I now heat this steel to redness, or put it into a state of mechanical vibration, the remaining magnetism almost entirely disappears, and we have apparent neutrality. the outside is reversed to its previous netism disappear. state. I place this piece of steel in a glass vase near the observing needle,

and at present there seems no polarity. I now pour dilute nitric acid upon it, filling up the vase. The exterior is now being dissolved, and in a few minutes you will see a strong polarity in the steel, as the exterior reversed polarity is dissolved in the acid.

Let us observe this by a different method. I take two strips of hard iron, and magnetize them both in the same di-

rection.

If I place them together and then separate them, there seems no change, although in reality the mere contact produced a commencement of reversal. Let us vibrate them whilst together allowing the molecules greater freedom to act as they feel inclined; and now, on separating, we see that one strip has exactly the opposite polarity to the other, both extremely strong, but the sum of which, when placed together, is zero, or neutrality.

Let us take two extremely soft strips placed together and magnetized whilst together. On withdrawal of the inducing force the rods are quite neutral.

We now separate these strips, and find that one is violently polarized in one direction, whilst the other is equally strong in the reversed, the sum of both being

again zero.

We might suppose that the reaction is due to having separate bars. I will now demonstrate that this is not the case by magnetizing this large $\frac{3}{4}$ -in. bar with a magnetizing force just sufficient to render the rod completely neutral when held vertically or under the earth's magnetic influence.

You notice that it is absolutely neutral, all parts as well as the ends showing not the slightest trace of polarization. I reverse this bar, and you perceive that it This is due is now intensely polarized. to the fact that the earth's influence uncovers or reverses the outside molecules, and consequently they are now of the same polarity as its interior. Upon reversing this rod the magnetism again disappears, and reappears if turned as previously. We have thus a rod which appears intensely magnetic when one of This piece of steel its ends is lowermost, whilst if that same being thin $(\frac{1}{2}$ millimeter), I know that end is turned upwards, all traces of mag-

INERTIA.

I have remarked in my researches that

the molecules have true inertia, that they resist being put in motion, and if put in motion will vanquish an opposing resistance by their simple momentum. lustrate this I take this large 3-in. bar magnetize it so that its south pole is at its lowest end. We know that the earth's influence is to make the lower end north. I now gently strike it with a wooden mallet, and the rod immediately falls to I continue these blows, but the rod obstinately refuses to pass the neutral line to become north, the reason being in so doing it would have to change the whole internal reversed curve that I have discovered. It requires now extremely violent and repeated blows from the mallet to make it obey the earth's in-

Let us repeat this experiment by starting the molecule rapidly in the first in-The rod is now magnetized stance. south, as before. I give one single sharp tap; the molecules run rapidly around, pass through neutrality, breaking up its curve, and arrive at once to strong north

polarity.

A very extraordinary effect is shown if we produce this effect by electricity; it then almost appears as if electricity itself had inertia. I take this bar of hard iron and magnetize it to a fixed degree. On the passage of the current you notice that the magnetism seems to be increased as the needle increases its arc, but this is caused by the deflection of the electric current in the bar. The current is now obliged to travel in spirals, as my researches have proved to me that electricity can only travel at right angles to the magnetic polar direction of a molecule, consequently in all permanent magnets the current must pass at right angles to the molecule, and its path will be that of Let us replace this bar by one a spiral. from a similar kind of iron, well annealed. The molecules here are in a great state of freedom. We now magnetize this rod to the same degree as in the previous case; the electric current now, instead of being deflected, completely rotates the molecules, and the needle returns to zero, all traces of external magnetism having ceased. The electricity on entering this bar should have been forced to follow a tortuous circular route; its momentum was, however, too great for the

lowing the electricity to pass in a straight line through the bar. Thus, in the first instant, magnetism was the master directing the course of the current; in the last it became its servant, obeying by turning itself to allow a straight path to its electric master.

SUPERPOSED MAGNETISM.

It is well known that we can suppose a weak contrary polarity upon an internal one of an opposite name. been enabled thus to superpose twenty successive strata of opposite polarities upon a single rod by simply diminishing the force at each reversal. I was anxious to prepare a steel wire so that in its ordinary state it would be neutral, but that, on giving it a torsion to the right one polarity would appear, whilst a torsion to the left would produce the opposite polarity. This I have accomplished by taking ordinary soft steel drill wire and magnetizing it strongly whilst under a torsion to the right, and more feebly with an opposite polarity when magnetized under torsion to the left.

The power of these wires, if properly prepared, is most remarkable, being able to reverse their polarity under torsion, as if they were completely saturated; and they preserve this power indefinitely if not touched by a magnet. It would be extremely difficult to explain the action of the rotative effects obtained in these wires under any other theory than that which I have advanced, and the absolute external neutrality that we obtain in them when the polarities are changing we know, from their structure, to be per-

fectly symmetrical.

I was anxious to show some mechanical movement produced by molecular rotation, consequently I have arranged two bells that are struck alternately by a polarized armature put in motion by the double polarized rod I have already described, but whose position, at three centimeters distant from the axis of the armature, remains invariably the same. magnetic armature consists of a horizontal light steel bar suspended by its central axle; the bells are thin wine-glasses, giving a clear musical tone, loud enough, by the force with which they are struck, to be clearly heard at some distance. The armature does not strike these altermolecules, and they elected to turn, all nately by a pendulous movement, as we

may easily strike only one continuously, the friction and inertia of the armature causing its movements to be perfectly dead beat when not driven by some external force, and it is kept in its zero position by a strong directive magnet placed beneath its axle.

The mechanical power obtained is extremely evident, and is sufficient to put the sluggish armature in rapid motion, striking the bells six times per second, and with a power sufficient to produce tones loud enough to be clearly heard in all parts of the hall of the institution.

There is nothing remarkable in the bells themselves, as they evidently could be rung if the armature was surrounded by a coil and worked by an electric current from a few cells. The marvel, however is in the small superposed steel magnetic wire, producing by slight elastic torsions from a single wire, 1 mill. in diameter, sufficient force from mere molecular rotation to entirely replace the coil and electric current. (Experiment shown by ringing the bells by the torsion of a small $\frac{1}{16}$ -in. wire placed 4in. distant from bell-hammer.)

CORRELATION OF FORCES.

There is at present a tendency to trace all physical forces to one, or rather a variation of modes of motion. In my last experiment the energy of my arm was transformed in the wire to molecular motion, producing evident polarity; this, again, acted upon the ether, putting the needle-hammer into mechanical motion. This by its impact upon the glass bells transformed its motions into sonorous vibrations; but this does not mean that we can convert directly sonorous vibrations into magnetism, or vice versa.

Let us take this soft iron rod; it seems quite neutral, although we know that the earth's magnetism is trying to rotate its molecules to north polarity at its lowest extremity. We now put it in mechanical vibration by striking it gently with a wooden mallet; the molecules at once rotate, and we have the expected strong north polarity. Let us repeat this experiment by employing heat, and here, again, at red heat an equally strong north polarity appears.

Again we repeat, and simply pass an electric current of no matter what direc- netism.

tion; again the same north pole appears. Thus, these forces must be very similar in nature, and may be fairly presumed to be vibrations, or modes of motion, having no directive tendency, except a slight one, as in the case of electricity; for the same three forces render the rod perfectly neutral, even when previously magnetized, when placed in a longitudinally

neutral field, as east and west.

Motion of the molecules gives rise to external magnetism to a rod previously neutral, or renders it neutral when previously magnetized; in other words, it simply allows the molecules to obey an external directing influence; the only motion, therefore, is during a change of state or polarity. If there is constant polarity there is no consequent motion of the molecules; in fact, the less motion of any kind that it can receive, the more perfect its retention of its previous position; consequently, constant magnetism cannot be looked upon as a mode of motion, neither vibratory nor rotatory. It is an inherent quality of each molecule, similar in its action to its chemical affinity, cohesion, or its polar power of crystallization. A molecule of all kinds of matter has numerous endowed qualities; they are inherent, and special in degree to the molecule itself. I regard the magnetic endowed qualities of all matter or ether to be inherent, and that they are rendered evident by rotation to a symmetrical arrangement in which their complete polar attractions are not satisfied.

Time will not allow me to show how completely this view explains all the phenomena of electro-magnetism, diamagnetism, earth currents—in fact, all the known effects of magnetism — up to the original cause of the direction of the molecules of the earth. To explain the first cause of the direction of the molecules of the earth would rest altogether upon an assumption as the first cause of the earth's rotation, and of all things, down to the inherent qualities of the molecule itself.

The mechanical theory of magnetism which I have advocated seems to me as fairly demonstrable as the mechanical theory of heat, and it gives me great pleasure to have been allowed to present you with my views on the theory of mag-

TRANSMISSION OF POWER BY BELTS, CORDS, AND WIRE ROPES.

BY GEORGES LELOUTRE.

From Abstracts of the Institution of Civil Engineers.

author upon this subject gave a summary of his researches; and these have since been detailed in the present extensive essay, to which was awarded in 1881 a gold medal offered to competition.

Having found that so-called practical formulas and rules are seldom of much value, in consequence of being made too general, the author twenty years ago began experiments of his own, which he has recently extended and rendered more complete. In his two first chapters he examines the facts relating to the stretching, elasticity, breaking, and slipping of cords and belts. Most of these facts run counter to the notions generally entertained. Above all, the influence of time on the elongation and breaking strain of belts, cords, and webbing, cannot be neglected.

The experiments on the elongation, elasticity, and breaking strength of belts were all made with dead weights, as described in the former abstract, so as to avoid the error arising from friction in testing by any lever machine. Detailed particulars are given of thirty experiments, the results of which are analyzed. The elastic stretching of leather belts under tension is by no means proportional to the strain: the amount of stretch increases much less rapidly than the strain, or, in other words, the modulus of elasticity rises with the strain. The resistance to stretching is greatest when the strain reaches about 850 lbs. per square inch of sectional area in leather belts; and in india-rubber and webbing at a rather lower strain. However rapid the stretching during the first hour, a considerable further elongation takes place when the strain is continued for two or three weeks; but two or three days' continuance is long enough to give a sufficiently accurate result for practical purposes.

In respect of elasticity, belts are stretching. Even when at rest, a belt dering; but the leather recovers its

A former abstract of a paper by the that remains on its pulleys continues to sustain throughout its length a strain equal to the mean between that on the driving and that on the trailing span when running. The elasticity of ordinary new leather is remarkable: a thong of very common leather, breaking at 2,280 lbs. per square inch, stretched as much as 22 per cent., of which it recovered at once rather less than half; and after fifteen months' rest it had returned to exactly its original length. There appears indeed to be no true permanent set for leather; it stretches to the same extent whether broken under a rapidly increasing load or under one applied for a long period, but in the former case it recovers more readily than in the latter.

The breaking strength for belts of all materials is from half as much again to twice as much when the load is increased up to the breaking strain in a few hours, as when that strain is slowly reached in the course of five or six months. ordinarily good leather the breaking strain when reached in an hour or two will be as high as 4,300 to 4,800 lbs. per square inch; but under loads slowly applied it will be only 2,850 lbs., and even less. India-rubber is rather weaker. Hence any results arrived at in trials that last only a few hours must be reduced in the above ratio for practical use. Though the strongest leather is not that which stretches least, yet in practice the mistake is generally made of looking for belts not to want tightening up too frequently, without regard to whether they are working at one-third or at one-sixth of their breaking strength. For a belt to last, however, the latter consideration is the more important: the leather employed should be the strongest and most elastic; and frequent tightening may readily be obviated by the simple expepedient of subjecting a fresh belt for some days before using it to a tension of from 1,050 to 1,450 lbs. per square inch. never in practice at rest or relaxed long Some belts are made of leather that has enough to recover wholly from their been compressed in thickness by calenoriginal thickness, just as it does its shortness after stretching. The tension which the author has been led to adopt for leather belts in practical working is from 640 to 780 lbs. per square inch, instead of the much lower strains generally recommended of only 200 to 350 lbs. The tensile strength does not appear to be impaired by repeated breakages. Hence the permanent load on belts may be made high, without fear of overstraining them or impairing their elasticity, their greatest strength being apparently developed under a tension of about 850 lbs. per square inch. Trying annealed iron wire, by way of analogy or contrast, the author found its breaking strength unaffected by the time occupied in testing; the first fracture diminished its elasticity, when thoroughly annealed, but not its strength; it undergoes sudden elongations after several days, to a greater or less extent according as the load is heavier or lighter; and lastly, under a load applied for a length of time, the stretch on breaking is about a third of what it is when the wire is broken in only about an hour's testing.

As to slipping, a very common mistake in practice is to suppose that the coefficient of friction, or ratio between the tensions of the driving and trailing spans of a cord or belt, increases with the size of cord or breadth of belt or diameter of pulley. But so long as the arc of contact on the pulley contains the same number of degrees, the size of cord, breadth of belt, and surface of contact, have absolutely no effect on the ratio between the two tensions at the moment when slipping is on the point of taking place. On this head the author's experiments are conclusive, ranging as they do from sewing thread up to hemp and cotton cords of $1\frac{1}{4}$ inch diameter, and from leather thongs only & inch wide up to belts 12 inches broad, with pulleys of from 8 inches to 8 feet diameter, on which the surface of contact varied in the ratio of 1 to 500, while the arc of contact ranged from half a turn (180°) up to $3\frac{1}{2}$ turns. What does modify the coefficient of friction for belts is their greasiness, and especially the degree of polish of the pulley-rims on which they

be nearly constant: it ranges from 0.070 to 0.075 for new cords, and from 0.090 to 0.180 for new leather belts that have not run long enough to get saturated with swarf; for old belts covered with a layer of dirt the coefficient is much higher; and when the pulleys are imperfectly polished it may rise to 0.300 and upwards. The coefficients commonly assumed are at least twice as high as these. When the pulley-rims are rounded over slightly convex in transverse section, the friction is rather less than when they are flat; for pulleys above 6 or 7 feet diameter the difference is immaterial. For well-greased belts the coefficient of friction diminishes as the tension increases; but this is only because the grease gets partly squeezed out when the belt runs tighter over the pulleys. The experiments were made by keying a pulley fast on a fixed horizontal shaft, and hanging a belt over it with equal weights at each end, and then gradually increasing the load on one end till the belt slipped. The trial must be continued long enough, because a load insufficient to cause in a few seconds any perceptible slip will produce a considerable slip in the course of hours. On the other hand, as the steady experimental pulley is free from the jar that occurs in all running pulleys, the adhesion is higher upon it than in actual practice. Moreover at high speeds of from 2,000 to 6,000 feet per minute a belt draws air in between itself and the pulley-rim, whereby the adhesion is impaired; this can be obviated by slotting holes at intervals through the rim, parallel to its edges, and the belt will thereby be kept running straight on the pulley.

The particulars and results are given in detail of eight experiments with cotton cords, ten with hemp cords, twenty-one with leather belts, and one with an indiarubber belt. From these experiments the author is led to adopt the following minimum values for the coefficient of friction, which give the corresponding ratios for the tensions of the driving and trailing spans when on the verge of slipping, the arc of contact with the pulley. being 180° in each case. For new cotton or hemp cords, coefficient 0.075; ratio of tensions 1.27 to 1.00 for pulleys with flat rims, to 1.45 to 1.00 for pulleys Throughout the author's experiments with semicircular grooves or with V the coefficient of friction was found to grooves having an angle of 80°, the nip-

ping of cord in the groove being neglected. For ordinary new leather belts, new india-rubber belts, and for wellgreased old leather belts, coefficient 0.200, ratio of tensions 1.90 to 1.00. No account is taken of extra adhesion from the pulley-rims being imperfectly polished or merely turned, because in working they gradually become more and more polished by the stretching of the belt

upon them under the load.

The practical examples, by which in his third chapter the author illustrates the application of his results to actual belt gearing, comprise the transmission of 42, 80, 280 and 700 horse-power by leather belts, and of 60 horse-power by an india-rubber belt: with regard to each of which the whole of the particulars are fully detailed and analyzed, including the description and strength of the belts, the loads on the bearings of the flywheel and pulley-shafts, the strength of the flywheel, the mode of joining the ends of the belt, and the relative advantages of cords and belts. Owing to the damaging effects of centrifugal force on lap-jointed belts, preference is given to butt-joints stitched with either one, two, or three thongs, through four rows of holes spaced zigzag, the stitching being so done as to range the thongs all parallel to the edges of the belt on its inner face, and diagonally on its outer; the thongs should be of very supple leather, such as the white kronenleder (crown-leather) obtained from Swit-Attention is drawn to the importance of flywheels being properly proportioned to the trains of toothed gearing they control, the flywheel being often made too heavy. The construction and strength of pulleys with curved arms is examined at much length. In regard to the relative friction with belts or cords and with toothed gearing, it is shown that theoretically the advantage is always more or less on the side of belts or cords; while a practical confirmation of this conclusion is furnished by the in- of stiffness of the iron wire ropes, and stance of a spinning mill, in which 0.000451 as the coefficient of air-resist-toothed gearing driving 18,000 spindles ance to the pulley arms. These coeffiwas replaced by belts, with a saving of cients are discussed, and confirmation is 20 per cent. in friction or 3½ per cent. on obtained for them from a comparison the effective driving power transmitted; with those hitherto accepted under difand in no case do belts practically cause ferent forms from recognized authorities more friction than toothed gearing. The upon the subject.

particulars are furnished of three examples where driving by belts did not coefficient 0.155, ratio 1.67 to 1.00. For prove thoroughly successful; and the conditions are pointed out which led to

the less satisfactory results.

The fourth and concluding chapter treats of the loss through friction and other dead resistances in transmitting power through great distances by means of wire ropes. This loss the author considers can be brought down as low as 30 or even 20 per cent. in transmitting power by ropes through distances of 6 to 7 miles and upwards. While electric transmission may be employed in connection with great mountain waterfalls, water-power nearer at hand may be utilized advantageously through ropes. The heavy outlay in each case is the same, being that incurred in constructing the necessary leats, or head and tail races, and in erecting the hydraulic motors themselves. The coefficient of friction for an iron wire rope in a round bottomed pulley groove that is lined with leather standing an end is found by the author's experiments to be 0.220 for half a turn round the pulley. From experiments at a spinning mill at Oberursel, Nassau, to which water-power is transmitted through iron wire ropes from a distance of 3,150 feet in eight spans of about 394 feet from pulley to pulley, it was found that, when using the maximum quantity of water, equivalent to 175 HP., the useful effect, tested by friction brake at the mill, was not more than 99 HP., or only 56 per cent. The aggregate loss of power, through friction of pulley bearings, stiffness of ropes, and resistance of air, ranged between 11½ and 12 HP. for seven of the above spans together. ropes were 0.59 inch diameter, and ran at about 55 to 60 miles an hour in ordinary working; the pulleys were 14.8 feet diameter, the weight of each with its cast iron axle being about 28 cwts. From these experiments the author deduces 0.090 as the coefficient of friction for the pulley bearings, 0.092 as the coefficient

ARRANGEMENTS FOR THE PREVENTION AND EXTINCTION OF FIRES IN THEATRES.

BY ERNEST A. E. WOODROW, A.R.I.B.A.

From the "Journal of the Society of Arts."

THEATRES should be entirely fire-resist- | wholly fire resisting; this can be aided ing, and have nothing in their construction that will readily ignite, so that the ordinary methods of extinguishing fire This can be attained by will suffice. giving due consideration and study to the planning and the materials of which the building is constructed. How these buildings can be planned and constructed, carrying out a safer system than at present, is what I would wish to try and point out in as brief a manner as possible, touching, it is feared but imperfectly, on only some of the most important points.

When the principal material employed in the construction is thin wood, as is, or perhaps I should say was, so often the case, no possible hope of safety could be entertained either for the building or

the public frequenting it.

That a theatre can be made safe in spite of the special dangers from the class of business carried on in it, there cannot be a doubt in the mind of any one who has given attention to the subject. Like every other class of building the special risks attending it can only be known by becoming thoroughly acquainted with the business carried on in it, and the special mode of conducting such business, with the accompanying dangers. Until this is ascertained, no one can possibly plan a theatre to avoid these risks, and ensure the safe and easy working of the house.

A theatre, of all buildings, should have a place for everything, and everything in its place; and it is necessary to know what this everything is before the place

for it can be provided.

The first step to be taken is to provide such means in the planning of the house as to enable the people to get out of the building in the shortest possible time, at the slightest provocation, in every way lessening the dangers from panic. Then, the construction of a theatre, and the materials used, should be such as to render it

greatly by the manner in which the various departments are placed with relation to each other.

As a theater can be made fire resisting no house should be allowed to remain open which is not so. It is no good to patch up the old wooden edifices with sheet iron and pugging, and expect that the buildings will be any the safer. If such theatres still exist in any part of the kingdom, they should be closed, even if the loss is sustained by the public themselves. When the slightest fire commences in one of these flimsy structures, as was seen at the fire at the Alhambra, no efforts, either from external or internal aid can possibly extinguish it.

Judgment in the choice of materials with which to construct the building, requires such great care and study that too much importance cannot be placed on this branch of the subject. The materials employed for the erection of places for the assembly of the public, whether for amusement, instruction or devotion, must be, in every sense of the words, "the best of their several kinds." The scantlings, or thicknesses, must be far in excess of what would appear to be necessary for the actual or present work which they have to perform, so that they may resist any shock or pressure that may from any cause be brought on them.

In short, a theatre must, of necessity, in comparison with other buildings, be exceedingly costly. In this I refer only to the structural portions, leaving all decorations out of the question. In dealing with buildings where human beings are "packed," surely more care should be bestowed upon their construction than upon warehouses or factories. But as long as cheap theatres are erected danger will be rife.

PLANNING AND CONSTRUCTION FOR PREVEN-TION OF FIRE.

No theatre should be allowed to stand

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that is "hemmed in on all sides with a space permit, the open area should be narrow entrance, as a frontage in a public thoroughfare sufficient to carry a flaming gas device." The dangers accruing from the surrounding property are often as great as those in the theatre itself. In no case should people be allowed to live and sleep in or about this class of building; the many risks necessarily attend- not in immediate use should be in this ing them through their own special trade building. should not be increased by the dangers generally to be met with in the dwellings of the lower class; and a building, or part of a building, not designed for the special business of a theatre, should never be used for such purposes, as it is nearly sure to be unfit for them.

The site should be isolated on all sides, wide streets running all around the building; but as this is difficult to obtain in crowded cities, a theatre might be designed with comparative safety having one side touching other buildings. To obtain perfect safety a site isolated on all

sides should be insisted on.

The most importent item in the planning is what might be called the partywall system, making every division of a theatre a separate building, with as few openings connecting the various sections and sub-sections as the smooth working of the house will allow. Commencing with the back of the building, I should place the workshop section, divided from the main building by an open area; then the stage, with dressing-rooms and wings on either side; then, of course, follows the auditorium the corridors, the staircases, and the offices and saloons. of these many sections must be divided from the other, vertically, by strong brick walls, with the openings closed by fire-resisting doors, and, horizontally, by fire resisting floors.

The various divisions within each section should be again separated by brick walls and strong, fire-resisting floors, so that, should one room be burnt out, no other part of the building would suffer. This system applies throughout the whole

building.

The position of the workshops should be such as to ensure an entirely separate open during a performance. Should were made for it elsewhere. It is here

made 12 feet wide between the theatre proper and the workshops.

Where no area can be obtained, a thick brick wall passing through and above the roof should divide the workshop section

from the stage section.

All stores for scenery, properties, &c.,

The painting gallery might be placed over the workshops, getting a top studio light, which should be protected by strong wire guards against falling sparks or materials. There is no special danger from scene painting, oil not being the medium used, as is sometimes supposed.

The stage is too often used as a carpenter's shop. This should never be allowed; the many dangers thus incurred need no pointing out; yet it is strange that seldom is a special room provided for the carpenters. The work in some houses was carried on over the auditorium ceiling, but this is happily stopped. A special workshop should always be provided.

Dressing-rooms might be placed on either side of the stage for males and females, being divided from the stage horizontally by brick arches, and vertically by brick walls. Fire-resisting staircases and separate exits into the street are necessary for each wing, as also for the workshop.

The fire places, where provided in the dressing-rooms, should be protected by tall wire guards. A complete system of heating throughout by hot-water pipes is, however, preferable to open fire-

The stage-floor and sliders must of necessity be of wood, for setting the scenes, but much on the machinery might be made of iron, keeping somewhat the same forms now used in wood, and making a stiffer stage, which could be more easily

manipulated.

On a level with the stage floor there must be ample room for scene docks, for storing the scenes in nightly use, while shifting from one set to another. mezzanine and cellars should be used building, connected with the theatre by only for the machinery for working the one opening only, which should be closed stage, and on no account should the by a double fire-resisting door, which stowage of rubbish or scenery be allowed door should on no account be allowed to here—it never would if proper provision that the stage carpenter does such infinite harm with his match-board erections, after the building is out of the hands of the architect.

The band and other rooms are at times but portions of the mezzanine, matchboarded off as if they had been forgotten when making the plans (which is more than likely). Proper accommodation must be supplied for band, band master, stage-manager, firemen, bill-sticker, property-master, &c., &c.

The gridiron above the stage must be made sufficiently strong to carry the weight of the cloths, &c. Cases have been known where it has given way under the weight of the scenery, and let everything in dangerous confusion down on to the stage. The construction of the gridiron, flies and flyrails should be of iron. Communication is necessary from the flies to the stage, to enable the flymen to escape.

The stage should be divided from the auditorium by a thick, solid brick proscenium wall, which wall should go between the orchestra and mezzanine, and be arched over the opening, passing through and above the roof. There need only be one opening in this wall, in addition to the large or proscenium opening, namely a pass door from the stage to the auditorium.

A separate fire-resisting passage way should be provided for the exit of the orchestra, so that the musicians may avoid passing either through the audience or under the stage to gain the street.

The stage should undoubtedly be cut off from the auditorium by some sort of fire-resisting or smoke-proof curtain. The failure of some of the iron curtains used on the Continent and in America has shown that they are not always to be relied on, but they must be of some use in retarding the progress of the flames. A double thick felt or cloth curtain, made bag shaped, and a water spray along the top that would damp the curitself as a method for shutting off the Water curtains have been prodesigned to act only in case of need, or put in darkness.

upon the outbreak of fire is often liable to fail at the very moment when it is most needed. Everything in and about a theatre must be always in use to be of Where automatic appliances any good. are provided, people are apt to put such faith in them that they ignore the ordinary and essential means of fighting against fire, and become careless of the importance of the great danger. "emergency" curtain coming down unexpectedly in the middle of the performance would be but the signal for a panic. Appliances requiring the presence of the flames which they are supposed to extinguish before they can act, cannot be too strongly condemned.

I repeat, and cannot insist upon it too strongly, all appliances must be made so that there will be no way of using them nightly. Therefore the smoke-proof curtain and the painted act drop should be made to fall always together.

The scenery should be protected by applying some of the numerous solutions recommended by our chemists, and all drapery should be similarly treated.

The woodwork in and about the stage should be periodically painted with asbestos paint, or other fire-resisting liquid, and no precaution left untried to mitigate the danger from fire.

In dealing with the stage, we have to contend with that portion of the house where there is the most danger from fire, the immense amount of gas used nightly, and sometimes in a careless manner, as pipes are being constantly connected and disconnected during the performance, causing small escapes near naked lights, makes one wonder that accidents occur as seldom as they do.

All lights must be protected by wireguards, and an arrangement should always be used whereby the gas is automatically cut off at the place where the union is made during the process of shifting various battens, ground-lights, &c.

The gas should be under the control of tain whenever it was lowered, suggests a practical gas man, with a sufficient staff of subordinates. This man should be stationed at the gas plate, which is fixed posed, but as these could not be periodi- on the stage during the performance, on cally tested on account of the destruction which plate each cock should be labeled of property that would ensue, they can-indicating what section of the light it, not be recommended. Whatever is adopt-governs, so that no error can possibly be ed must be in constant use, for anything made, and the wrong part of the house

The mode of lighting up should be by the electric spark, and not by naked lights. The "flash" system should be applied to all battens and hanging lights, avoiding the use of the spirit, cotton, and cane moving among the scenery. When the electric light is used, many of the dangers of stage illumination will be done away with; yet great care will have to be taken in the manipulation of the light, which need not be touched on here.

The gas-meters should be placed in a specially prepared and ventilated room. The supply pipes must be of hard metal, visible, and coated to prevent corrosion. There should be a cut-off tap near the stage door, to turn off the gas from without in case of fire. Separate meters should be provided for every section of the house, and a double supply laid on to each. Every set of staircases, corridors, offices, dressing-rooms, workshops, as well as the stage and auditorium, should have a dual system of lighting.

Every burner should be protected by an incombustible guard, and fixed away from woodwork or inflammable material. with a metal flue over it. In the parts of the house frequented by the rougher class, the lights should be encased, or locked up, or placed out of reach.

Sun-burners are preferable to gasoliers; these must be periodically cleaned, and no woodwork fixed near them. Access should be provided to them from the roof.

Oil lamps should be placed about the buildings in all sections, in conspicuous positions, but out of the reach of the public, to take the place of gas on its Colza oil has been found preferable to any other. Red lamps, with the word "Exit" in white, should be placed over the exit doors. All lamps should be lit and in their places before the doors are open, and the gas, both on the stage and in the auditorium, should be lit before the audience is admitted.

Gas-burners fixed so that they can be tampered with are among the most prolific sources of producing fire. should be no jointed brackets or swinging pendants; every fitting must be fixed, and all joints and appliances examined and approved before the house is licensed.

Proper precaution should be taken in the manipulation of the lime light, and the bags kept outside the buildings.

made to enable the use of artificial light being discontinued during the day, thus avoiding one of the greatest risks in theatres, namely, the careless handling of lamps, candles, or matches. It is a frequent habit to drop the end of a semiburnt match, and one to which great danger is attached. There could never be a greater mistake than making a theatre dark. The business could be better carried on if there were plenty of daylight, and the accumulation of the dirt of years would not then be suffered to remain unremoved, ready to flare up on coming in contact with the slightest spark. A theatre, for everybody's comfort, should be clean; but as long as it remains dark, it will be dirty and dangerous. Therefore, the removal of rubbish should be insisted on daily, or an external furnace provided in which it could be consumed.

The roof should have easy access from various points, and be provided with cat ladders, leading from the different levels, to enable firemen to get about with ease. There should be a parapet wall all round to protect the firemen. The construction of the stage roof should be of iron; if of wood, the constant changes of temperature to which it would be subject, and the enormous heat, would desiccate the trusses and rafters, and convert them into something little better than touchwood, which would readily ignite.

A better mode of constructing an auditorium roof could not be cited than that of the new Alhambra Theatre, where iron and concrete, with a covering of asphalte, are the materials used. The ceiling of the auditorium should be formed of fireresisting materials, such as Jackson's fibrous plaster, and never of canvas. There should be no space over the ceiling available for store or workshop.

The several divisions of the audience should each have their separate entrances, exits, passages, corridors, staircases, saloons, lavatories, &c. The best method of planning this portion of the house, having in view the safety of the people, would be to bring everybody as near the level of the street as possible. To do this, place the dress circle on the street level, go down to the pit, and up to the upper circle and gallery. By adopting this method, the various sections of the audience would have a better chance of Provision for plenty of light should be gaining the street, the distances being

more distributed. The fact of the building not being so high as it would be if the pit were on a level with the street, would give a better chance of aid in case of fire; and as the parts occupied by the administrative officers need not be carried so high as the main building, an intermethree, should be admitted, slopes should diate roof could be obtained, whereby the principal roof could be easily reached being below the level of the street, would not be in any danger, as in going upstairs a crowd is not likely to stumble, there not being the same risk as when coming down stairs.

have two entrances and exits, one on each side of the house, such exits and their approaches leading directly into the street, and these should be used only by that section of the audience for which they are designed, there being no passdoors or emergency exits leading from other parts of the house into them. A door that is known as an "emergency a rule, leads into a corridor or staircase of the house. trances, and entrances exits, and used inside with ease. Locks are bad, as keys nightly.

Staircases and passage-ways should be quired. from 4 ft. 6 in. to 5 ft. wide. Where this ordinary barrel-bolt was terribly illuswidth is insufficient for the number of trated in the case of the Sunderland dispeople, an extra staircase should be pro- aster. It is apt to slip and catch in the vided rather than additional width being floor, fixing the doors. A fastening is given beyond the 5 ft. The corridors wanted that will enable those inside to immediately outside the various tiers get out, while it will at the same time should be of sufficient width to take the present an effectual barrier to those outpeople occupying such tiers without side. crushing. These corridors must be di- invention known as "Arnott's patent bolt," vided from the auditorium by brick walls, in which an ordinary spring square bolt and the openings fitted with fire-resisting has the lower portion knuckle hinged.

half landings in the staircases, as all such and become parallel with the floor, thus are dangerous in a moving crowd. The allowing the door to swing both ways. flights should not be of more than eight Pressure from the outside will only tightor ten steps, and the treads and risers en the bolt. What are now known as should be of easy and uniform go "emergency" doors are too often found throughout. All steps and landings must locked, and worse than useless. have at least 4½ inches bearing on solid brick walls at both ends, and arches means of getting out of a theatre, there should be turned under the landings.

doors.

tween the wall and the hand-rail. acquire this, a chase should be cut in the wall, so as not to lessen the width of the staircase or passage-way by the projection of the hand-rail.

No single step, or flights of two or

take their places.

The private box staircases should be from without. The people in the pit, made as important as the other staircases, with exits into the street, and communication at each level. As a rule, they are narrow or corkscrew staircases, only available for the private boxes.

There should be no unshipping of bar-Each section of the audience should riers; they should be made permanent, and hung so as to open outwards, and

close against the wall.

No pay-box or barrier should be placed to obstruct the exits; the movable box so often seen should be abolished, and the pay-box made part of the permanent

building.

All doors and barriers must be hung so as to open outwards, and close against door" is only a trap; when opened, it, as the walls, the larger doors being hung in two folds. The fastenings on the doors already full of people from another part used by the public should be such as to All exits must be en- allow them to open the doors from the are seldom forthcoming when most re-The danger attendant upon the This has been provided by an Pressure on the inside will cause this There should be no winders or steps at portion of the bolt to leave the socket,

If the public were acquainted with the is no doubt they would feel safer when Strong hand-rails, on brackets built visiting these places of amusement. into the walls, should be fixed to both great number enter with the idea that sides of all flights of steps and landings, they could never find their way out if leaving a space of three inches clear be-they wanted; this is not to be wondered

at, considering what some of these entrances are, and that the entrances are not always the exits, and the exits not always used nightly. Everything should be done to inspire the audience with the idea that they could save themselves without hurting others in case of accident. To do this they should be able to find their way easily about the house. Several ideas to attain this suggest themselves placing ample notices on walls and doors, such as "Exit;" "This way out;" printing the plan of each section of the house separately on the programmes; placing large plans of the house in conspicuous positions; but above all, simplicity and uniformity in the plan at the first onset. Place the exits where they will be easily seen, and make both sides of the house as nearly alike as possible. Notices should be painted on lavatory, saloondoors, &c., to distinguish them from exit doors. All notices should be painted in luminous paint. Never should such notices as "In case of need," "Exit in case of fire," "In case of panic," "Emergency," "Alarm exit," be seen; they only suggest danger to the people, and everything should be done to intimate safety and avoid panic among the nervous visitors to theatres.

All seats should be numbered, and the house licensed to hold that number, and no more admitted under penalty of heavy fines to manager and visitor alike, then the gangways would be left unobstructed; but until they are both equally fined, the passages will be blocked by people standing or seated on loose chairs. All seats should be fastened to the floor, and made to tip up, to allow more room between each row for exit.

As far as the contents of the auditorium are concerned, it may be presumed that it is impossible to do without carpets, curtains, and stuffing to the seats, otherwise there need be nothing inflammable in the furniture.

The floor should be laid with blocks of hard wood, over the fire-resisting floors, for comfort.

As many bodies which are incombustible under normal conditions become inflammable at a high temperature, every means should be taken to keep a theatre cool, adding to the health, comfort, and safety of all. When heat is much concentrated, it makes substances highly inflammable, which might at a low temperature be simply combustible; it is therefore necessary, to prevent fire, to provide proper ventilation in a theatre. How often is this done?

The stage should be well ventilated, and at the same time there must be no draught to cause the scenery to wave about. Metallic shafts, with gas jets burning in them, fixed in several places above the gridiron, would draw off the vitiated and heated atmosphere and smoke in case of fire; but should a fire break out, the upward draught would increase it to a very serious extent; but if the gas jets were turned out, and the proscenium curtain lowered, the draught would be

greatly lessened.

Fresh air should be admitted to the auditorium as near the floor level as possible, being previously warmed. The number of inlet shafts should have some relation to the numbers occupying the seats, and the manner in which the vitiated air is drawn out of the building. Sunburners play an important part in extracting the foul air, but, in addition, every gas-burner should have over it a funnelshaped flue, up which the products of combustion might pass. It must be borne in mind that perfect ventilation is imperceptible; but to acquire such ventilation has been found a hard task, therefore theatres have been left to take care of themselves, and in but few cases the slightest provision taken to render them little better than death-traps. Whether the mode applied be what is known the vacuum or natural system, the plenum or mechanical, seems of little moment, provided fresh air is continually admitted throughout the whole house. The number of deaths occasioned through breathing the foul, poisonous, and heated air of our theatres is far in excess of those caused by fire and panic. It would be as well if some of the numerous authorities which govern places of entertainment in this country were to turn their attention to this fact; but I fear the familiar adage may only too truly be said of theatre regulation, that "too many cooks spoil the broth." Large sums of money have been expended in providing means to avert dangers that may occur some day, while the fact that thousands nightly breathe the poison that will bring disease and untimely death with

it, even to the strong, is totally ignored. Lightning conductors should be fixed at various points outside the building.

MATERIALS FOR PREVENTION OF FIRE.

The accepted idea of what is fire-proof is a very mistaken one. Materials that are incombustible are not therefore fireproof; take iron and stone, both accepted legally as fireproof, and both among the first substances that will succumb to the influence of heat and sudden change of temperature. To give an idea how totally mistaken some are as to the fire-resisting qualities of materials, I have known lead suggested as a substance to be used to render floors fireproof. Lead, of all materials, is the most dangerous, and the most dreaded by the fireman.

The walls must be solid and very thick, well bonded into each other, of good sound bricks; bond timbers should not be admitted, but hoop iron bond should be Every opening should have an arch turned over it, the use of lintels, either of stone or wood, being discarded. The walls should be corbelled out to

receive the floors.

The floors, where possible, should be supported on brick arches abutting against brickwork, but on no account against iron. When the floors are constructed of iron and concrete, the iron should be completely embedded in the concrete, and the concrete should have the aggregate of calcined material, such as broken bricks, clinkers, or broken The circles should either be pottery. constructed of iron and concrete, or of timber in large balk, and of the hardest description, such as elm or oak, which should be thoroughly protected from the action of fire by thick coatings of plaster; gypsum, or plaster of Paris, is well adapted for this purpose.

Where iron columns are used, they should be protected by a thickness of fire-resisting plaster or cement, held to the columns with a good key. posts of the harder woods would suffer less from the changes of temperature than iron, but their thickness would de-

stroy a good deal of the sighting. The ordinary thin iron doors are of no use to resist fire. If iron doors were

but it would be a very difficult task to do this to every door in a theatre. Thick oak doors would resist fire for a long Wooden doors, lined with sheet iron or zinc, would be more effective than the thin iron doors so often met with; none of these, however, would be fireproof, although fire resisting to a certain extent. A perfect fire-resisting door could be made on the same system as safe doors, having an inner case of iron packed with sawdust and alum, surrounded by a strong, well-bound and well-hung outer These would be heavy and expencase. sive, and as all fire-resisting doors must be hung to close automatically, they would be dangerous; but they should be fitted to divide the greatest risks, such as the workshop section from the stage, the stage from the auditorium.

Steps and landings should be made solid, of approved artificial stone, fireclay, or concrete, whose aggregate has already been burnt. Stone should be avoided, as, in the words of Captain Shaw —a man whose opinion on such subjects is the best in the world—it yields to fire more rapidly than any other material, is the most dangerous of all materials, as at sudden changes of temperature it cracks,

leaving a passage for smoke.

That unprotected iron is unsafe, owing to the risk of fracture, and the loss of strength attendant upon great heat, is a fact well known, and as it is sometimes applied, it is a source of great danger, assisting in the destruction of the building, as its contraction or expansion will thrust out or pull down the walls, and even when covered with cement, it will suffer in great heat. Wood is only a dangerous material when used in thin slices. "It will withstand a powerful dead heat upon its sides for an indefinite period without igniting, unless transverse sections of the fibre, such as a knot, presents itself to the action of fire. used in large balk of the harder kinds, and protected with plaster, it is infinitely safer than naked iron.

The use of plaster as a fire-protecting agent I would strongly advocate: it is light, and resists fire for an indefinite

period.

It would perhaps be as well to enumerplaced on both faces of the walls the ate some of the many causes from which space between might be filled up with fires in theatres have originated and besome wet materials to keep them cool; come fatal, before considering the last of fires.

Bad arrangement and planning of the various sections, and not making each an independent fire risk, and not providing separate accommodation for each department or trade.

Danger from contiguous houses, and from people living in and about the the-

Bad judgment in the choice of materials, and bad or faulty construction.

Foul or imperfect flues.

Darkness and dirt, and keeping rubbish, shavings, &c., on the premises.

Smoking in the theatre proper.

Overheating through lack of proper ventilation.

Unprotected gas-lights, and escape of gas from imperfect fittings.

Upsetting oil lamps.

Using matches or other naked lights. Imperfect system of electric lighting.

Accumulation of heat round the sunburner, and not cleaning same.

Carelessness in the manipulation of the stage during a performance.

The use of firearms, fireworks, and colored fires.

The want of a properly organized fire watch, defective fire appliances, and lack

Carelessness among workmen, such as

carpenters and plumbers.

Lightning, concentrated rays of the sun by means of lens, spontaneous combustion, and incendiarism.

EXTINCTION OF FIRE.

When a building has been constructed that will in every way retard the spread of fire and panic, it should be considered how, should the fire, in spite of all the precautions, occur, it could be most effect-

ually coped with.

A theatre, from the nature of its business and contents, cannot be fire-proof, although fire-resisting; but there is no ment in which they originate. means, therefore, should be taken to

part of our subject, namely, the extinction prevent the loss of much life and prop-

erty.

As regards fire appliances, there should be an unsparing supply of fire-buckets, always full of water, in all parts and sections of the building; more good can be done with these, if used in time, than any elaborate appliance that may come into use when the fire has got a hold. buckets should be made conspicuous, labeled "fire-buckets," painted red, and never allowed out of their place. Handpumps, with and without pails, should be distributed about the building, with a few chemical engines. Hydrants should be mounted on the rising main on every floor, in every section, and every 40 feet apart, having the hose "married" and ready for action. All proper tools and implements should be near at hand, wet sponges, wet blankets, hatchets, axes, &c., &c., being distributed about the stage and other parts. There should be a cock on each hydrant to fill buckets from. Hydrants should also be placed outside the building, and on the roof.

All fire appliances in these buildings should be periodically tested by the authorities; for the lack of this they are too often, on an emergency, found to be useless. The pattern of the appliances should be similar to that of the brigade of the town in which the theatre is situated, so that the theatre and town appliances may

be used indiscriminately.

Ladders should be fixed from the roof to within 20 feet of the ground, where external aid can easily reach them. Iron balconies should be provided to windows.

It seems almost needless to say that there should be a sufficient supply of water, at a pressure strong enough to reach the highest part of the building. In towers formed at a height above the roof, there should be large water tanks, as a secondary supply, supposing the main failed at any time, but too much reliance must not be placed on tank hy-Experience has taught us that drants. reason why fires should not be localized the tanks are too often empty, or only and burn themselves out in the depart- partly full, owing to the want of a con-Every stant supply from the water companies.

So much has been said upon the desirextinguish fire. Water is the element to ability of employing brigade firemen, well overcome fire; it is cheap, and can be versed in their business, in lieu of the, in obtained in large quantities, and if there in more senses than one, "theatrical fireis some at hand when a fire first breaks man," that I need not repeat the arguout, a jug-full, judiciously used, would ments in favor of the brigade men. Two

trained firemen should be in charge of the house from an hour before the performance till daylight, and two others should have charge during the day, all four being present when the house is open. The stage should never be left during the performance, and at the same time it would inspire the audience with confidence to see firemen walking about the auditorium. By the day watch the appliances should be cleaned and kept in repair, everything being tested every day at a fixed hour, say 6 p. m., just before the audience is admitted.

It should be the duty of the firemen to keep everything in working order, and they should be required to do nothing else. Imagine a stage without a responsible fireman, if, in the full swing of a pantomime, a small fire occurred. easy to conceive the confusion there would be among the numerous young and nervous people employed on the stage. The noise behind, even supposing the curtain to be down, would cause fear and panic among the audience, and a stampede might be the result. But if steady, experienced men, always ready for action, are employed, and the buckets and appliances are always in their places and in order, with plenty of water at hand, there need be no fear of fires on the stage. there are many theatres in which the water supply is insufficient, the appliances imperfect, and no organized fire-watch in existence.

To extinguish fires on the stage, a suggestion has been made that a series of perforated pipes be fixed to the under side of the gridiron, or to the gas battens, governed by a series of stop-cocks on the stage. By this means the scenery that had not already ignited might be moistened, and the spread of fire stopped, but a great destruction of property would ensue. Far better get at the heart of the fire with a hand-pump or bucket of water.

Telegraphic communication should be held with the nearest fire-station. Too much reliance should not be placed on emergency fire-alarms. People are apt to become careless when they put their confidence in these appliances; they are also liable to act when no danger exists, especially in this class of building, where tificates from the Metropolitan Board of the temperature at times is so high; and, on the other hand, when most needed dangers may in a year or two arise, they may be out of order through disuse. through alterations being made, per-

All check-takers and attendants should wear uniform, to be conspicuous, so that they may be better able to manage the people on an emergency. They should attend fire drills, and be able to help the firemen when needed. For the same reasons it is well to have a policeman or two about the building.

To extinguish fire, provide good and sound appliances, plenty of water, and a good watch.

Theatres are luxuries, and to enter some of them one pays dearly, both as regards money and the risk of losing one's life. If we pay so highly, surely we should be better protected while there. But the system seems to be to work the house as cheaply as possible, and to pack as many into it as it will hold, at as high a price as they will pay.

After every consideration is given to the disposition and construction of the building, and it has been passed by the authorities, the architect, under whose supervision the house has been built, hands it over to the manager for the rest of its existence, except in rare cases where the architect receives a fixed remuneration for periodical visits—which should be the case everywhere. As a rule, the manager is a man of refinement and education, who will do everything in his power to protect the public and make the house popular. But for all that there should be a further continuous inspection supervising the management, as is being advocated by Mr. Dixon-Hartland in his bill now before the House of Commons. A staff of inspectors knowing the architectural arrangement, and the business peculiar to theatres, should be appointed, with power to visit the houses at all odd times, before, after, during the performance, in the day, and even in the middle of the night, unbeknown to the management. Reports as to the condition in which they find the house, and the way in which it is being worked, should then be made to the one recognized authority which should take the place of the many that now exist.

In theatres which at present hold cer-Works as being structurally safe, fresh some risk is attached. There are other matters requiring supervision besides structural defect, i. e., ventilation, water the whole establishment. Until these inspectors are appointed, the public cannot be protected as they ought to be; on the other hand, it would be useless to make managers suffer from more official to fill the posts who are qualified through a theatre.

haps trivial in themselves, but to which previous experience in the modus operandi of theatre management and construction.

Once more I would strongly urge that supply, and the general management of the best safeguards against fire are good planning and construction, perfect ventilation, light, and scrupulous cleanliness; that the best means to extinguish fire are a good fire-watch and plenty of water; and that on no account should inspection, unless the men can be found "emergency" appliances be relied on in

DENUDATION BY RIVERS.

From "The Engineer."

tical hydraulic engineer has to deal, periments, arrives at very much the same there are few more important, and few, engaged the attention of engineers from an early period, and the formulæ laid eral of these same formulæ, the object down on the subject by Dubuat, Eytelbeing to test the value of the formula wein and others date from centuries ago. Their experiments, however, were mostly conducted on channels of very small section, and it has long been recognized that to extend these to natural rivers, or even to channels of different dimensions, is to commit a grave error. Numerous formulæ have since been introduced, in the hopes of improving on the results of these early experimenters. Turning, for Molesworth's *Pocketbook*, we find that the mere list of such formulæ occupies almost a page of small print, and that at least twenty authorities are there mentioned by name as having contributed to the subject. But as a striking commentary on their success a small table is given at the bottom of the same page, where four cases of actual discharge, varying from 24 to over 1,000,000 cubic calculated results for the same conditions, least 50 per cent. Nor is this a solitary in thousandths of an inch per annum, is

Among the many important and com-instance. Major Cunningham, in his replicated questions with which the practicent work on the Roorkee hydraulic exresult. Again, in papers published in our perhaps, more complicated, than that of issue of November 1st, 1872, p. 293, the the discharge of water through open results given in the classical experiments Naturally, therefore, it has of D'Arcy and Bazin are compared with the calculated results derived from sevobtained from theoretical considerations by the late Canon Moseley. Any one who will turn back to these figures will see divergences startling enough to prove that we must at least use considerable caution in adopting any formula for such purposes; and yet the conditions were here unusually favorable, as the experiments were carried on, not in the difficult and irregular channel of an actual instance, to the well-known pages of river, but in an artificial conduit specially prepared for the purpose. In spite of these facts, which it is impossible to deny, nothing is more common than to see the most confident and offhand statements made as to the discharge of all sorts of rivers under all sorts of circumstances. To take one example, derived from the science of geology: It is frequently stated in geological works—as, for instance, by Mr. Alfred Wallace, and feet per second are compared with the by Professor Geikie in his late admirable Manual of Geology—that a certain defiderived from nine approved rules on the nite thickness of earthis removed from the subject. The differences are very strik-surface of the land every year by the rivers ing; in some cases they amount to nearly which flow through it, and is by them emp-100 per cent., and in many cases to at tied into the sea. The actual thickness,

given with all the confidence of an approved scientific fact. We have never been able to trace this statement to its original source, but we have no hesitation, as practical engineers, in pronouncing it to be altogether visionary. It is worth while to consider for a few moments what data would be requisite before such a figure could be laid down, even to the very roughest degree of ap-

proximation. Of course, the only possible method of determining it lies in measuring, by some mode or other, the quantity of mud -or silt, to use the most general termwhich all the rivers, say, of this country, carry into the sea during the course of a single year. What would any engineer do if he was given the commission of carrying out such an inquiry? He would have, in the first instance, to ascertain the mean annual discharge of every river or stream emptying itself into the tidal estuaries of Great Britain. It would be worse than useless to conduct observations upon these estuaries themselves, because it is perfectly well known that the silt suspended in such waters at any moment gives no evidence whatever as to the amount of silt which is conveyed into these estuaries from the uplands during each Therefore it would be vain, year or day. for instance, to compute the silt carried down by the Thames from observations taken below Tedington Weir; we must examine the Thames itself above that weir, and all the streams which enter into it lower down must be subjected to a separate investigation. Let us consider next what will be necessary in the case of any one of those streams. In the first place our engineer must have the means of measuring its discharge with sufficient accuracy on any particular occasion he may desire. We have said enough already to show that this is an exceedingly difficult matter, that he will be unwise if he relies even upon the best of the dozen or so of formulæ amongst which he may take his choice; and that he is, in duty bound, to make an accurate determination in the case of each river in order to take full account of local conditions. Let depth of the current, with its velocity, and us assume that he has done so, and that with the contour of the bottom, with the he is thus able by a series of observations to ascertain with fair correctness posed, and probably with many other the discharge taking place on any partic-local circumstances. It will not do, ular day. It is obvious that to measure therefore, to trust to anything less than

this discharge for a single day only would be utterly futile. During a winter flood many rivers, even in England, will send down 50 to 100 times the water in an hour compared to that which dribbles over their bottom towards the end of a summer drought. Our engineer must, therefore, measure all the great floods which occur during the year he has selected, and must also take a large number of measurements both in the wet and dry seasons. This done, he must search carefully the meteorological records of the district—if he can find any—in order to ascertain whether this particular year may be taken as a fair average example, and if not, he must make such addition to or subtraction from his results as his own judgment shall direct him. Failing this, he will have no recourse but to renew his observations from year to year, until in the lapse, say, of a generation, a true average can be struck. At the end of this time, provided there are no indications of a progressive change in the climate and rainfall, he may fairly be allowed to state what the mean annual discharge of this particular stream may be.

But his work is only begun after all; it is not the quantity of water discharged which he is in search of, but the quantity He has to determine not only the number of cubic feet of water which has flowed through his channel in a particular year or a particular half century, but how much solid matter each of these cubic feet held in suspension while it passed. To do this it will by no means suffice to pick up a bucketful every time that he makes an observation, have it carefully evaporated, and weigh the residue which remains. We know scarcely anything of the laws of distribution of suspended matter within the waters of a stream. It may, indeed, be as sumed that the quantity per cubic foot will be larger towards the bottom than towards the top of the current; but the law according to which this varies is quite unknown. All that we can be sure of is that this law itself will vary, probably very largely, with the material of which that bottom is comthe collection of a large number of samples, say 50 to 100, from all parts of the cross section, on each occasion when the discharge is measured, or at any rate, on each occasion when the river is in an abnormal condition. Suppose this to be done and the weight of silt per cubic foot at each of these places to be ascertained by the slow method of evaporation and weighing, then it will by no means do to strike an average of all the fifty and multiply this by the number of cubic feet discharged per hour; for the velocities at different parts of the cross section are very different, and this will clearly modify the results. Thus, if the velocity at the bottom is half that at the top, whilst the weight of silt per cubic foot is double, it will be seen that the amount of silt carried down per square foot of area at the bottom and at the surface will be really the same. Hence, we must know the average velocity in each of the fifty divisions, say into which our cross section has been partitioned off for convenience, and we must also know the average weight of silt per cubic foot corresponding to that division. Multiplying together each pair in these two series of numbers and adding the products thus obtained, we shall arrive at some sort of approximation towards the quantity of silt which our stream was carrying down per hour, on the day when this particular observation was taken; and the same process will have to be repeated for every one of the separate observations which have been described as being necessary in order to solve the problem of mean The annual discharge. experiments must necessarily be conducted over a considerable number of years, because it is quite possible that the effects of drainage, denudation, or other causes may produce a progressive increase or diminution of the average quantity of silt borne down, and of this it will be necessary to take account.

So much for our single river; we have now to perform the same task for every other river and stream, from the largest to the smallest, which empties into a tideway around the coast of our island. The smaller streams will no doubt, give less show, however faintly and inadequately, means at hand of estimating the number to ascertain the correctness of the figure of such streams, but assuming that there which geologists quote so confidently, viz.,

is merely one for each mile of coast, it will be evident that it will be considerably over 1,000. Supposing, however, that the whole of these have been gauged, and the discharge of silt calculated in the manner just described, we may perhaps imagine that our engineer's task is at an end. Not a bit of it. He has to ascertain not merely how much solid matter has been carried into the sea per annum, but how thick a layer of solid matter has been subtracted from the land. Now, the quantity of the solid matter upon the land is being added to every year by the operation of certain very obvious causes, such as the falling of leaves, the decay of plants and animals, the application of foreign manures, &c. Possibly some one may object that organisms, whether plants or animals, can only build up their substance from materials already existing in the earth, but a moment's reflection will show that a large part of their substance is derived either from water or from air. It is precisely this decaying organic matter, lying, as it does, at or near the surface of the ground, which will be washed off in the greatest proportion by rain and by rills, and will so find its way into the rivers, and thence to the sea. Therefore, our engineer must of necessity do one of two things: he must either analyze carefully every ounce of silt recovered in his observations in order to ascertain beyond a doubt, first, how much of it is due to organic and how much to inorganic matter; secondly, how much organic matter was derived from the earth and how much from air and water; or, failing this, he must by some means or other calculate the whole volume of matter which has been added to the earth by the causes above mentioned, he must measure the quantity which remains at the end of that period, and he must subtract the difference—or rather the difference less that part of it which is due primarily to inorganic constituents—from the total amount which he has already ascertained to form the burden of the rivers as they fall into the sea.

We have, perhaps, said enough to trouble than the larger, but they must by no means be neglected. We have no would have before him if he were set the thickness of the layer of soil which with perfect confidence, as if it was is removed annually from our British Isles by the operation of what is called sub-aerial waste. A feeling of longing and regret steals over us as we close the record. What a pity that the determination of this figure is not a matter of paramount national importance to be settled at any cost! and what a pity that we ourselves are not given the responsible task of settling it! It would resemble one of those magnificent Chancery suits which an attorney of the old school was wont to regard with so much complacency and satisfaction; a suit which he could slowly administer during his life-time, and hand on to his children with his blessing on his deathbed, certain that it would remain as a sure and comfortable source of income to them and their children yet

And yet geologists quote this figure reflection or research.

known to the 10,000th of an inch. They do more—they calculate on this basis the number of years which will elapse before Great Britain becomes a dead level, totally forgetting that the diminution of slope all over the country will wholly change the conditions of the problem. They do this in the name of science, and in the next breath inform us that science is measurement!

Our geological problem has detained us so long, even in the mere stating of it, that we have no space left to consider further the special engineering problem —that of determining the discharge of rivers—with which we set out. hope, however, to return to it at no distant date, having perhaps said enough, even here, to show that it is not one to be settled off-hand, and without either

ELECTRICAL CONDUCTORS.

BY WILLIAM HENRY PREECE, F.R.S., M. Inst. C.E. Proceedings of the Institution of Civil Engineers.

I.

mutual dependence and reaction between used in England, and it was buried practice and theory been more beneficial than in the useful appliances of electricity. Without theory the rule-of-thumb telegraphist would have been stationary. Without practice the electrician would have been a dreamer. The practical difficulties of telegraphy incited the physicist to trace out the laws that govern the behavior of this subtle Power of Nature, and the appearance of new facts has driven the practical telegraphist into lines of inquiry and discovery. Physicists have been metamorphosed into practical engineers, while no telegraph engineer deserves that title unless he also possesses that as a scientific man.

These conclusions are very strongly illustrated by the improvements made in the quality of the conductors employed for the transmission of electric currents.

Copper.—In the first telegraphs of 1837 nothing but copper wire, owing to

In no branch of engineering has the its high position as a conductor, was underground; but the difficulty then experienced in insulating buried wires was so great, that they were removed from underground and suspended on poles.* ductility, the want of tensile The strength, and the absence of elasticity of copper, as then produced, rendered it impracticable for this purpose. It was speedily replaced by iron. Iron has since been almost universally used for aerial lines, while copper remains the sole material for underground and subpurposes where mechanical marine strength is of little consequence. Mechanical strength and price seem to have been the only considerations that governed the choice of conductors in the earlier days; but as soon as speed of transmission assumed a commercial aspect, as it did in 1858, when Atlantic telegraphy was an accomplished fact,

^{*} In 1848 a copper wire was put up between Paris and

then the electrical qualities of the material engaged the attention of the telegraph engineer. Sir William Thomson in 1856 pointed out the great differences in conductivity observable in various samples submitted to him, although these samples were supposed to be of the very best quality; while the late Mr. Augustus Matthiessen in 1860 made an exhaustive inquiry into these variations and their causes. He determined the electrical conductivity of pure copper, and defined a standard which is that now in use,† and showed that the variations were due to impurities, principally oxygen and metalloids. A mere trace of arsenic reduced the conductivity 40 per cent., while contact with air when in a molten state reduced it 24 per cent.

The result of Matthiessen's inquiries has been not only to remove the great variations in the conductivity of the copper, but to immensely improve its qual-While in 1861 electricians were itv. content to specify that the copper should not fall below 85 per cent. of pure copper, they now specify 96 per cent, and they obtain it of a remarkable uniform quality. The value of this improvement may be estimated from the fact, that the carrying capacity of a cable for messages is increased in the same proportion as the conductivity of the copper is improved. Thus a cable made of the copper of to-day will carry twice the number of messages that a similar cable of copper would in 1858.

The progressive improvement is shown by the following table:

•	J		
•	Cable.	Year.	Conductivity.
Dove	r and Calais	185	1 42.00
	atrick and Donaghade		
Atlan	itic Cable	185	
	Sea		
	and Alexandria		
Persi	an Gulf	186	
	itic Cables		
Irish	Cable	188	3 97.90
Pure	copper		. 100.00

It is not, however, alone in cables that an improvement of working has been effected by increasing the conductivity of the copper. It has imported additional efficiency to the apparatus. Greater useful effects are obtained with the same current. In all the practical applications of the current, it has an econ-

omical advantage, for it lessens the waste of energy in the circuit in direct proportion to the improvement effected. In an electric-light main a difference of 10 per cent. in the purity of the copper might lead to the waste of several HP. The test for purity is extremely simple. Every text-book, or book of tables, has the resistance of a foot-grain, a metergramme, a mile-pound, or a knot-pound,* of pure copper at every degree of ordinary temperatures—call this R_t . Take a piece of the cylindrical conductor to be Let w be its weight, l its measured. length, the

 $\frac{\mathbf{R}_t \ l^2}{w} = r_1$

gives its resistance at the temperature at the point of observation if it be truly cylindrical and the copper be pure; but by actual measurement it will be found to be r_2 . Then

$$\frac{r_1}{r_2} = \frac{100}{x}$$
, or $x = 100 \times \frac{r_2}{r_1}$.

and x is its percentage of purity.

The resistance of all metals is very much affected by temperature. Mathiessen studied this with great care. He found that within ordinary limits the increase due to higher temperatures was approximately expressed by the formula.

$$R_t = R_0 (1 + a t),$$

where R_o is the resistance at 0° and R_t the resistance at the temperature t. He ascertained the coefficient a to be for pure copper 0.0038. Thus the resistance is increased 38 per cent. between the freezing and boiling points, and it may therefore be increased 20 per cent. between winter and summer temperatures. Hence it is desirable to determine the efficiency of electric-light leads at the highest temperature to which they will be exposed, to avoid unnecessary and injurious waste of energy.

But copper is not only used for submarine cables and for underground lines; it is also employed for overhead wires through towns and many smoky districts. It is not so readily attacked by

[†] Mathiessen's standard is 100 inches, weighing 100 grains, giving 0.1516 ohm at 60° Fahrenheit.

weighing
* 1 metre 1 gramme = 0.144 ohm at 0° C.
1 foot 1 grain = 0.2064 ""
1 knot 1 pound = 1091.22 ""
1 mile " = 842 ""

the gases in the air as in iron or zinc. For such purposes, however, mechanical strength, which is of little consequence fine wires rendered them brittle, and in insulated wires, becomes of essential

importance.

Copper wire when in the process of manufacture is always drawn cold, and is said to be "hard-drawn" before it is subjected to the annealing process, after which it is called "soft." Soft copper always gives a higher conductivity than hard-drawn copper, but its tensile and its alloys, particularly brass, become strength is reduced. Pure soft copper brittle when exposed to atmospheric inhas a very small breaking strain, probably under 10 tons on the square inch, but hard-drawn copper is now supplied that conductors. has a breaking strain of 28 tons on the square inch.

Copper wire has been erected in localities where iron wire is destroyed in a few months, and now, after four years' experience, it appears practically un-The diameter of the wire has not been lessened $\frac{1}{1000}$ inch, and it maintains its original qualities unimpaired. In the neighborhood of chemical, varnish and other works it becomes encrusted with a thick deposit, but beneath this it

remains unaffected. Age alone, as far as experience extends, seems to have no appreciable influence on the quality of unstrained has been removed from magnet coils, it becomes brittle, but curiously enough ful economical result. found that silk-covered wire, particularly non-scientific practice. of the finer sizes, wound upon experiequally brittle, whether the instrument is thrown aside or whether it is continuously at work. Neither paraffin nor electro-gilding checks this brittleness. It is probably an effect due to the strains that the wire experiences when wound on a reel and subject to the incessant variations due to change of temperature.

duced by the passage of electric currents. furnaces, some of which have been so The conductors of the Atlantic cables successful that there is no difficulty in laid in 1858, 1865 and 1866 are found as getting metal giving an electrical conperfect now as when they were made. ductivity equal to 99 per cent. of pure The conductors of all cables seem to copper. Great purity of copper is also remain constant. But Gaston Planté arrived at by electro-deposition, of which

discovered that the continued discharge of great quantities of electricity through Callaud asserted that lightning conductors were very brittle. If that be so, some result may be anticipated from the employment of currents for electric lighting. At present there has scarcely been sufficient experience to teach much on this point.

It is well known that impure copper fluences in workshops, but this influence has not been observed in telegraphic

Wires more than twenty years old, used as battery leads, and constantly subject to the transference of electricity through them, show no signs of deterioration. The experience of telegraph engineers is entirely in favor of the constancy and durability of copper as a conductor.

The size of conductors is governed by strictly theoretical conditions, dependent upon the purposes to which they are applied, and it is controlled by commercial considerations. In telegraphy, speed of working is the criterion; in electric lighting, and in the transmission of power, waste of energy is the criterion. William Thomson has given a law which copper. Its conductivity and its ductility indicates, that the annual value of the remain constant. But when copper wire wasted energy must equal the interest on the capital expended in laying down such as the field magnets of a dynamo, the conductor to give the maximum use-Any departure this seems to occur even when the from this law, to secure low capital exmagnets are out of use. Mr. Sabine has penditure, means shortsighted policy and

Copper is imported into the country mental apparatus, gets in a few years either as ore or as regulus, bar or ingot. The purest comes either from Japan, Chili, Australia, or from Lake Superior. Much pure copper is produced by the Swansea method of copper-smelting, especially by the modification of that system known as "best selecting;" but within the last few years very pure copper for electrical purposes has been obtained by improvements in the treatment Mathiesen observed no difference pro- of the metal in the smelting and refining

there are two methods: the one by depositing the metal from a solution obtained from the ore, the other by using impure copper as the anode in a depositing bath containing a standard solution. Electro-deposited copper has not the same mechanical strength as ordinarily refined copper.

At the Paris Electrical Exhibition of 1881 there was one coil of copper wire 1.3 millimeter in diameter, weighing 181 kilogrammes, and measuring 15 kilom-

eters long.

Iron.—Iron has been hitherto used exclusively for overhead wires. In the first days of gutta-percha, about 1849, iron was employed as the conductor to be coated with the new gum, but its inapplicability for this purpose was speedily discovered. Its abundance, its cheapness, and its admirable mechanical properties have singled it out for practical telegraphic purposes; but its resistance is very high, and materially increases the difficulties of the telegraphic engineer. The great improvements effected in the electrical qualities of copper, directed attention to the same qualities in iron; but although copper has been so vastly improved, the same progress has not been made with iron. Copper refiners have relied more upon the aid of the chemist than iron-ware manufactur-In fact the improvements made have been forced upon the latter. process in this case has been more tentative and less scientific. There is still room for progress. Although the author had for many years advocated attention to this point, the Americans were the first to specify conductivity in applying They defined a standard for tenders. which was called the Ohm-mile—that is, it was the weight of a cylindrical wire 1 mile in length, which gave a resistance of one ohm at 60° Fahrenheit. While the first iron wire supplied under this specification gave a mile-ohm* of 5,500 lbs., it is now frequently obtained as low as 4,520 lbs. In the present specification of the Post Office the fixed maximum resistance is equivalent to a mile-ohm of 4,800 lbs.

The amelioration made in the quality of iron wire is illustrated by the following measurements:

Inch. Ohms. 1873 Iron wire......0.171 15.31 per mile.0.17111.30

In the earlier days of the telegraph best puddled iron was used for wire, which, however, was very liable to splits and flaws, and an alteration was made by using piled puddled iron or BB (best-This description was again improved by the introduction of "boxpiled iron" of puddled and English charcoal, sometimes called extra B B, and by four-sided charcoal-piled iron of English charcoal and puddled, which has been called extra special B B; but the terms B B, &c., have now lost all significance—the commonest description of fencing wire only being known by the term. During the last decade a mild English Bessemer steel has been very largely employed, especially for railway telegraphs, and for staying purposes; but the resistance of most wires of this description is high, averaging about 6,800 lbs. per mile-ohm, this high resistance being mainly due to the high percentage of manganese, which in this description of wire varies from 0.25 to 0.75 per cent. The wire used by the Post Office is Swedish charcoal, with a mile-ohm resistance, as already stated, of about 4,520 lbs. Swedish Bessemer, or a specially prepared low carbon English Bessemer, is used by the Indian Government, with a mile-ohm resistance of Cast-steel wire, with a about 5,400. breaking weight of about 80 tons to the square inch, has been adopted on the Continent for telephone circuits with a mile-ohm resistance of 8,000 lbs. The table will show at a glance the various descriptions of iron and of steel telegraph wire which are now in use, or have been used, the tests being given for 0.171 inch, or 400 lbs. to the mile, that being the standard size in England, and a size very largely employed throughout the world.

It will be noticed by the following table, that while in England, where speed of working is the prime consideration, and length of span may be neglected, electricians are satisfied with a breaking strain of 22 tons on the square inch; in the Colonies, where long spans are essential, and speed of working is not so important, the specification is 30 tons

on the square inch.

^{*} Mile-ohm is more euphonious than ohm-mile, and is used in preference.—W. H. P.

The following chemical analysis of samples of different wires, with their approximate resistances and tensile strengths when annealed for use as telegraph wire, will be interesting:

Analysis of Samples of Different Wire.

- No. 1. Swedish Charcoal Iron, very soft and
 - " 2. Swedish Charcoal Iron, good for P. O. specification.

- The following chemical analysis of No. 3. Swedish Charcoal Iron, not suited for mples of different wires with their P. O. specification.
 - " 4. Swedish Siemens-Martin Steel, 0.10 carbon.
 - " 5 Best Puddled Iron.
 - " 6 Bessemer Steel, special soft quality, 0.15 carbon.
 - "7 Bessemer Steel, special hard quality, 0.45 carbon.
 - " 8 Best Cast Steel.

MECHANICAL AND ELECTRICAL TESTS OF SEVEN DESCRIPTIONS OF IRON TELEGRAPH WIRE.

Four samples of each kind.

Description.	Diame- ter.	Twists in 6 inches.	Elonga-	Break- ing Weight.	Resistance per Mile reduced to 0.171 inch at 60° Fahr.
1. "B B" puddled iron	$ \begin{array}{r} 174\frac{1}{2} \\ 176\frac{1}{2} \\ 165 \\ 173\frac{1}{2} \end{array} $	$ \begin{array}{c} 16 \\ 13 \\ 14 \\ 17\frac{1}{2} \end{array} $	Per cent. $17\frac{1}{2}$ $11\frac{1}{2}$ $15\frac{1}{2}$ 14	lbs. 1,470 1,380 1,436 1,182	14.4200 13.5592 13.8897 13.8983
2. "B B" piled iron, all puddled $\left\{\begin{array}{cccc} & & & \\ & & & \\ & & & \end{array}\right.$	$ \begin{array}{r} 171 \\ 164\frac{1}{2} \\ 164\frac{1}{2} \\ 172\frac{1}{2} \end{array} $	$ \begin{array}{c} 16 \\ 9 \\ 12 \\ 17\frac{1}{2} \end{array} $	$ \begin{array}{c} 17 \\ 13 \\ 11\frac{1}{2} \\ 16\frac{1}{2} \end{array} $	1,220 1,316 1,238 1,292	14.0582 15.5820 15.6234 14.1640
3. "Extra B B." Box piled of puddled and English charcoal, thus— E. C. $ \begin{array}{c c} E. C. \\ \hline P & P & P \\ \hline P & P & P \end{array} $ E. C.	$\begin{cases} 168 \\ 174 \\ 169\frac{1}{2} \\ 172 \end{cases}$	$ \begin{array}{c c} 11 \\ 10\frac{1}{2} \\ 11\frac{1}{2} \\ 12 \end{array} $	$14\frac{1}{2}$ 15 16 $14\frac{1}{2}$	1,456 1,538 1,398 1,452	15.6191 15.3715 15.5452 15.3017
4. "Extra special B B" Four-sided charcoal-piled English charcoal, and puddled thus— $ \begin{array}{c c} E. C. \\ \hline E. C. \\ \hline P P \\ E. C. \end{array} $ E. C.	$\begin{cases} 172 \\ 168\frac{1}{2} \\ 172 \\ 172 \end{cases}$	$15 \\ 14 \\ 10\frac{1}{2} \\ 15$	15 14½ 14 16	1,420 1,412 1,484 1,478	15.5129 15.6844 16.3574 15.5471
5. English Bessemer (known as homogeneous iron) $ \left\{ \begin{array}{c} \\ \end{array} \right.$	$ \begin{array}{c} 171\frac{1}{4} \\ 169 \\ 170 \\ 168\frac{3}{4} \end{array} $	$\begin{array}{c} 20 \\ 19 \\ 19\frac{1}{2} \\ 12 \end{array}$	$ \begin{array}{c} 16 \\ 13\frac{1}{2} \\ 17\frac{1}{2} \\ 14 \end{array} $	1,634 2,118 1,484 2,548	15.9988 18.5663 14.6922 19.1480
6. Swedish Bessemer	$173\frac{1}{2}$ $174\frac{1}{2}$ $173\frac{1}{2}$ $171\frac{1}{2}$	$\begin{array}{c} 21 \\ 20\frac{1}{2} \\ 22 \\ 13\frac{1}{2} \end{array}$	17 12 18 17±	1,392 1,380 1,456 1,318	12.6808 12.9709 13.6587 13.0222
7. Swedish charcoal	$ \begin{array}{c} 171 \\ 169\frac{1}{2} \\ 169\frac{1}{2} \\ 171\frac{1}{4} \end{array} $	23 25 24½ 27½	$ \begin{array}{c} 13\frac{1}{2} \\ 10 \\ 13\frac{1}{2} \\ 13 \end{array} $	1,191 1,358 1,194 1,128	11.3490 11.3052 11.2241 11.3133

No. of Samples.	1	2	3	4	5	6	7	8
Carbon		0.100 trace 0.022 0.045 0.030 trace 99.700	0.150 0.018 0.019 0.058 0.234 trace 99.440	0.100 trace 0.035 0.034 0.324 trace 99.600	0.100 0.090 0.030 0.218 0.234 0.015 99.110	0.150 0.018 0.092 0.077 0.720 trace 98.740	0.440 0.028 0.126 0.103 1.296 trace 98.200	0.620 0.060 0.074 0.051 1.584 trace 97.410
Mile-ohm at 60° F.	lbs. 4,546	lbs. 4,502	lbs. 4,820	lbs. 5,308	lbs. 5,974	lbs. 6,163	lbs. 7,468	lbs. 8,033

This table shows in a very striking way that the electrical conductivity of iron wire increases with the percentage of pure iron, except where the percentage of manganese is high; an increase in the percentage of manganese augments the electrical resistance considerably more than an increase in the percentage of

sulphur or phosphorus.

The durability of iron wire is maintained by galvanizing—a most inappropriate title for a very simple operation. The wire, which is first chemically cleaned by being passed through a bath of hydrochloric acid, is then drawn through a bath of molten zinc, at such a pace as will secure the adhesion of the requisite layer of zinc. The zinc becomes oxidized when exposed to the air, and since zinc-oxide is insoluble in water, the wire is protected with an impervious coating; but when this zinc-oxide is exposed to sulphur acids it becomes converted into zinc sulphate, which is soluble. Hence the zinc is removed, the iron is exposed, and oxidation and destruction rapidly supervene.

When the galvanized wire is to be suspended in smoky districts, it is additionally protected by a braided covering, In some countries, galvanwell tarred. izing is not resorted to, but simple oiling with boiled linseed oil is depended upon. Such a wire was erected in 1856 between London and Rugby, but the result was very unsatisfactory. More recently (1881) the experiment has been repeated with a similar result. In this climate galvaniza-

tion is imperative.

But it is not alone in smoky districts where iron wire decays. It suffers much along the seashore. speedily reduced to mere thin red lines. the author would mention how much

Where external decay is not evident, time seems to have no apparent effect on iron wire. Wire that has been erected for forty years seems as strong, as elastic, and as conductive as it was at first. pure country air its durability seems infinite; but sometimes, especially through fir forests, it is subject to some corroding influence. Bauschinger in 1878 tested iron taken from bridges that had been erected in 1827 and in 1852, and found the strength and elasticity unimpaired. Thurston found the same in Philadelphia after forty years' exposure. Thirty-nine years of incessant service in conveying currents for telegraphy have not apparently altered the molecular structure of iron wires in the open country on the London and South Western Railway.

Manufacture.—Swedish charcoal iron being now the only description used by the British Post Office, the author has selected it for describing the manufacture of iron telegraph wire. It is imported either in bloom or in rods (principally in rods.) Each rod is rolled down to about. 0.26 inch in diameter, and weighs on

the average about 1 cwt.

Iron wires used to be drawn in very short lengths, weighing from 15 to 20 lbs., involving numerous welds, splices, or joints—points of great weakness but now they can be rolled and drawn into lengths longer than are practically required. Coils 0.171 inch in diameter, weighing 400 lbs. and measuring 1 mile have been exhibited, but 110 lbs. is about the best practical limit for transport and use.

By the mills invented by Mr. George The salt spray Bedson, of Richard Johnson and Nephdecomposes the zinc oxide into soluble ews, Manchester, the billets can be rolled compounds, which are washed away and in this country without welds into rods leave the iron exposed, and this is weighing upwards of 1 ton in weight; and telegraph engineers are indebted for the third for torsive capacity. man.

The Swedish iron owes its value not only to its comparative purity, but to the fact that it is smelted and puddled entirely with charcoal. The best qualities are a mixture of various ores, and they secrets.

The rods arrive in this country dirty and rusty, and the first operation is to cleanse them. This is done by immersion in a bath of diluted sulphuric acid which thoroughly removes every trace of oxide and dirt. The clean rods are then coated with lime to prevent further oxidation, and well baked to dry off all trace of One end of each rod is next pointed to admit of insertion in the draw-hole, and it is then drawn down by one operation to No. 5 W. G., or 0.212 inch in diameter. The act of drawing the wire considerably modifies its molecular structure. It becomes "short," and before it can be drawn down to a smaller size, it must be well and carefully annealed. It is then again cleaned and coated with lime, and reduced to 0.171 Since the drawing inch in diameter. down has again shortened the texture, it has once more to be annealed, before receiving its final operation of galvaniza-After galvanization it is straightened by being drawn through a series of jockey rollers, and wound round two wheels, one of which has a slightly quicker motion than the other. It is finally gauged and tested befsre being stored away for future use.

facture of 400 lbs. wire which is that principally adopted for telegraphic purposes in England, but the explanation is equally applicable to any other size—the ment to produce the high results rewire after each drawing being annealed.

Testing.—The operation of testing is are mechanical and electrical. strain, another for elongation, and a not found in practice. Equally difficult

For hard modern improvements in telegraph wire steel wire, in place of the torsion test, to the various inventions of this gentle- it is usual to specify that the wire shall bear wrapping round its own diameter and unwrapping again without breaking. In France the torsion test is replaced by another by which the wire is bent at a right angle backwards and forwards four times for wire 4 mm. in diameter. Speare known by various brands, the condicial machines are constructed for the tions determining these brands being mechanical tests, the condition to be fulfilled being that for the breaking strain the increasing load or stress shall be applied uniformly, without jerks or jumps, and the elongation machine shall correctly register the actual stretch without the wire slipping. The torsive capacity of the wire is determined by an ink mark which forms a spiral on the wire during torsion, the number of spirals indicating the number of twists taken before breaking. The electrical test is simply that for resistance of a mile of the wire to be examined is wound round a dry wooden drum; and its electrical resistance is taken in ohms by means of a Wheatstone's bridge. Galvanization is tested by dipping in sulphate of copper, and by bending or rolling round a bar of varying diameter, according to the size of the wire.

Specification.—The perfection to which the manufacture of iron wire has been brought is greatly due to the care bestowed upon the specifications by the authorities of the Post Office and of the India Office. No lesson of experience has been neglected; no point has been left open to doubt. The standard has been gradually raised, until it is now very high. It is fixed, and not subject to those continual changes that are irritat-The author has described the manu- ing and expensive to the manufacturers. who have in consequence been able to select their materials, and to ascertain by experiment the best methods of treatquired.

It cannot be too strongly urged that a most important one, and requisite not specification without rigid inspection is only for the user, but also for the manu-valueless. The manufacturer who for facturer. Flaws, impurities, faults, not- his own reputation, and in obedience to withstanding the greatest care, will occur, the dictates of his conscience, strictly and they can be detected only by the complies with the requirements of a most rigid examination and tests. Tests rigid specification at the expense of his The pocket, without the check of a subsequent mechanical tests embrace one for breaking inspection, may exist in theory, but he is

is it to find the careful and painstaking inspector who, possessing the requisite technical knowledge and experience, will rigidly perform his task, regardless of the blandishments of those whose interests are affected by his blindness or carelessness. Many administrations object to the expense of thorough inspection, and the result is they are the recipients of the rejected material of those who do rigidly inspect. One break in the wire costs far more than its inspection, and one extra ohm per mile affects the earning capacity of the wire in inverse proportion.

It is, however, necessary to remark that the mechanical quality of charcoal iron wire sometimes changes with time—its electrical quality remaining unaffected. The molecules seem to set, and the wire to decome harder. This is shown by a diminution in the number of twists, and by an increase in the tensile strength. Tests repeated at some subsequent period may therefore be deceptive, unless allowance be made for the effect of time. Bessemer or homogeneous iron wire as a rule improves in its mechanical proper-

ties by being kept in stock.

Gauge.—The vexed question of gauge as applied to wire has been fought with well-nigh the same energy as that of railway gauges. The result is, that confusion has become more confounded. The various Birmingham wire gauges as various as the seats of the manufacture of iron—were consolidated into one very useful gauge by the Society of Telegraph Engineers; but the Board of Trade has recently taken up the subject, and has issued another gauge, which has the merit of being authorized, It is fixed and legal, and therefore must be accepted. However, it departs so seriously from all recognized gauges, and ignores so completely the metrical system, which is steadily and surely making its way into commercial use, that the Post Office authorities have decided to abandon a gauge altogether as applied to conductors, and to define size by diameter and weight. Thus, in future, all copper wires will be known by their diameters in "mils," or thousandths of an inch, and all iron wires by their weights in lbs. per The following table gives the iron wires generally in use:

Diameter.		
inch.	millimetres.	
0.242	6.0	
$0.209 \\ 0.171$	5.2 4.3	
0.121	3.0 1.85	
	inch. 0.242 0.209 0.171	

Steel wire is used for long spans, or for places where great tensile strength is needed; but it is for the external strengthening of deep-sea cables that steel wire is principally adapted. It was first employed in the Atlantic cable of 1865 for this purpose. It has since been generally used for deep-sea cables. The usual diameter is 0.099 in., and it is specified to bear a breaking strain of 1,400 lbs, which is equivalent to 81 tons on the square inch. Steel wire has been produced giving a much higher tensile strength.

Compound Wire.—A compound wire of steel and copper was introduced in America about 1874. It had a steel core for strength with an envelope of copper to secure conductivity and durability. has a weight only one third of an iron wire of the same resistance. It has been extensively tried in both hemispheres, but without success. It has been impossible to secure permanent adhesion of the envelope and its core. Moisture has in course of time entered, the steel has corroded away, and this, even though the copper envelope has been deposited electrolytically. Light wires of great strength and of low resistance would be of inestimable value to the telegraph engineer, and the failure of the compound wire has been a source of much regret.

Recently a compound wire has been erected between New York and Chicago, a distance of 1,000 miles, giving only 1.7 ohm-resistance per mile. It has a steel core 0.125 inch in diameter, and is coated with copper electrolytically to a diameter of 0.25 inch; it weighs 700 lbs. per mile. It is very expensive. Hard-drawn copper or silicium bronze of a much lighter character would be equally efficient, at probably one-half the cost.

Bronze Wire.—Phosphor bronze, the hard, mechanical qualities and great resisting powers of which are well known, was introduced for telegraph wire about five years ago. Several lengths were

^{*} The "mil" is one-thousandth of an inch.

erected by the Post Office. Two long hence the silicium bronze is preferable spans cross the channel that separates for telegraphic purposes. Its efficiency the Mumbles Lighthouse from the head- is very great; in fact, phosphor bronze land near Swansea. The object in view has disappeared for telegraph wire, and was to obtain great tensile strength, with has been replaced by silicium bronze. a power to resist oxidation, especially active where the wire is exposed to sea can be made nearly equal to that of copspray. This was done in 1879, and now, per, but its mechanical strength is diminin November, 1883, not the slightest ished as its conductivity is increased. change is noticeable in the wire. But Wire whose conductivity equals 90 per phosphor bronze, though extensively cent. of pure copper, gives a tensile used, has high electrical resistance; its strength of 28 tons on the square inch; conductivity is only 20 per cent. that of but when its conductivity is 34 per cent. copper. Moreover, the phosphor bronze of pure copper, its strength is 50 tons on originally supplied was irregular in di- the square inch. Its lightness, combined mensions and brittle in character. It with its mechanical strength, its high improvements have recently been intro-render it eminently adapted for teleduced to remedy these disadvantages.

Phosphor and silicium bronze derive their names not so much because phos-some tests made by the Post Office upon copper, but because they are used in the submitted for trial. preparation of the alloy. Pure bronze is the alloy.

The conductivity of silicium bronze would not bear bends or kinks. Great conductivity and its indestructibility, graphs.

The table below gives the results of phorus and silicium are mixed with the different specimens of bronze and copper

Long telegraphic lines, for which iron a mixture of copper and tin, and in the wire weighing 400 lbs. per mile is now refining and mixing process phosphorus used, can be made of copper or of bronze and silicium have the property of remov- wire weighing 100 lbs. per mile, which ing impurities, particularly the oxides, would give higher electrical efficiency; though doubtless some of the flux reand over-house lines, for which steel wire mains. Phosphorus has a most injurious is often used, can now be replaced effiinfluence on the electrical resistance of ciently by wire weighing only 30 lbs. per Silicium is far superior; mile, which would be almost invisible.

EXPERIMENTS ON DIFFERENT QUALITIES OF WIRE.

Dia	meter.	Weight per Mile	Elongation	Breaking Weight in Tons per	Twists		ance in at 60° F.	Sonductivity.
Inch.	Mm.	in Pounds	Per Cent.	Square Inch.	in 6 inches.	Per Mile.	Per Foot- Grain.	Conductivity. Copper=100
Silicit	JM- BRONZE—							
.080	2 056	102.650	$\{1.5:1.0\}\ \{2.0:2.0\}$	27.610	13:16 23:35	8.6359	0.22258	94.616
.059	1.529	58.651	nil nil	29.368	21:25 27:58	15.4370	0.22734	92.637
. 044	1 133	32.310	nil nıl	47.406	24:25 24:26	90.3330	0.73285	22.826
.036	0.936	-22.698	nil nil	50.070	23:19 11:22	157.3900	1.43750	14.650
.081	2.072	102.170	$\{1.5:1.0\}$	$29.022 \}$ $27.470 \}$	47:19 16:20	8.5009	0.21807	96.571
Сорре	R—							
.081	2.072	106.100	nil nil	30-322	16	_11.3490	0.30235	69.60
.082	2.088	107.630	1.5:2.5	29.164	27	9.4400	0.25538	82 50
.0847	2.136	116 400	0.5:1	3J.306	50	9.2400	0.26995	78.00
. 081	2.072	105.310	0.5	28.416	84	8.4100	0.22245	94.60

If such overhead wires were erected upon sightly supports, and with some method there would be an end to the meaningless crusade that is now made in some quarters against aerial lines. These, if constructed judiciously, and under proper control, are far more efficient than underground lines. Corporations and local authorities should control the erection, rather than force administrations to needless expense and to reduced efficiency by putting them underground. Not only do light wires hold less snow and less wind, but they produce less electrical disturbance; they can be rendered noiseless, and they allow existing supports to carry a much greater number of wires. Other bronzes have been tried, but without any evident advantage, either in quality or in price.

German Silver.—German silver is employed generally for rheostats, resistance coils, and other parts of apparatus in which high resistance is required. It

consists of:

Copper4	parts.
Nickel	- 66
Zinc1	6.6

The variation in its resistance due to changes of temperature is small. Its coefficient is 0.0004—copper being 0.0038—that is, about ten times less. Its resistance per meter gramme is 1.85 ohm,

while copper is 0.144 ohm. The effect of age on German silver is very marked; it becomes brittle. Mr. Willoughby-Smith has found a similar change with age, even in the case of wire drawn from an alloy of gold and silver.

Conclusion.—It is evident, from what has been said, that the form and character of electrical conductors must vary with the purposes for which they are intended. For submarine cables and for electric light mains, where mechanical strength is not required, and where dimensions are of the utmost consequence, the conductors must be constructed of the purest copper producible, for copper is the best practical material at our command.

On the other hand, aerial lines must not only have great tensile strength, but in these days of high-speed apparatus they must have high conductivity, their dimensions must be such as to ensure low electrostatic capacity, they must expose to wind and snow the least possible surface, and they must be practically indestructible. Iron has hitherto occupied the field, but copper and alloys of copper seem in many instances destined to supplant that metal, and to fulfill all the conditions required in a more efficient way, and at no greater cost per mile.

SOLUTION OF TRIGONOMETRICAL PROBLEMS BY CONTINUED APPROXIMATIONS.

BY HORACE ANDREWS, Jr., Assistant, New York State Survey.

Written for Van Nostrand's Engineering Magazine.

In solving trigonometrical problems from a diagram. the results will be more or less precise, depending upon the number of decimals employed, when logarithmic tables are used; or upon the size of the drawing, if the results are deduced graphically.

from a diagram. problem, much used ings and subordinate lation, a good example to convenience of the As illustrations,

It is frequently very convenient to obtain approximate values of the quantities desired by means of a roughly-drawn diagram, and then to increase the precision of the results to any desired extent. This method is especially valuable where the direct process of computation is complicated, and where the approximate values can be very readily obtained

from a diagram. In the three-point problem, much used for locating soundings and subordinate points of a triangulation, a good example is found of the convenience of the method.

As illustrations, two simple problems of plane trigonometry will be taken.

The principles involved are

1st. The sines of the angles of a plane triangle are proportionate to the opposite sides.

tent. This method is especially valuable where the direct process of computation is complicated, and where the approximate values can be very readily obtained A, where M is the modulus of the com-

mon system of logarithms; log. M sin 1"=1.32335, for units of the seventh place of decimals, or M sin 1"=0,-0000021 05.

3d. Cot. B+cot C=
$$\frac{\sin (B+C)}{\sin B \cdot \sin C}$$
.

Problem.—Given two sides b and c. and the included angle A of a plane triangle, to find the remaining parts B, C and a.

Where the large letters denote the angles and the small letters the opposite sides.

Example.— $A=75^{\circ}24'.09''.206$, log. b=4.2965477 $\log c = 4.4184219$

From a rough diagram

values of $\log b \sin A$ and $\log c \sin A$, then, using only five places at present, the values of log. $\frac{b \sin A}{\sin B}$, and log. $\frac{c \sin A}{\sin C}$. These two values of log. a differ by 28100 in units of the seventh place of

The first step is to compute precise

By using four-place logarithms the we have

decimals.

value of log. $\frac{1}{\text{M sin } 1'' \text{ sin } A}$ is first computed, and then the value of the 1st correction 818" is obtained. It is evident that in order to secure a closer agreement in the values of log. a, B must be increased by 818", while C is diminished by the same amount. Making these changes, and using now six places,

The second correction, 2."042, must be subtracted from C and added to B.

 $\log b \sin A = 4.2822976$ B=42° 04′ 30″.836 log. sin=9.8261433 approximate log. a=4.45615438.6909 difference between logs.log.=0.9542 $\log c \sin A = 4 4041718$ $\log \sin B = 9.8261$ $C=62^{\circ} 31' 19''.958 \log. \sin = 9 9480166$ log. sin C=9.9480 0".263....9.4192 approximate log. a=4.4561552

4.2822976 B=42° 04′ 30″.573 9.8261427 log. a 4.4561549 4.4041718 C=62° 31′ 20″.221 9.9480168 log. a 4 4561550

can be expected, unless more than sevenplace tables are employed. The process of computation could be stopped at any point where the resulting values of log. α are thought to be sufficiently close.

The operations described above are of a very simple nature. In practice the computer would make some more conve-An agreement now is found as close as nient arrangement of figures than that

given. The time required for the computation will then be found to be less than by the ordinary methods.

For most purposes the values of B, C and log. a, found at the end of the second trial, where only six places were

used, would be precise enough.

To illustrate the advantages of a more concise arrangement the computation is repeated below. Seven-place logarithms are here used after the first correction has been obtained, and only one more correction is then found to be necessary.

B=41°50′50″.794	42°04′28″.794 30″.545
$\log a = 4.45807$	4.456 1590 1549
log. sin B=9.82422	9.826 1386 1427
log. b sin A=4.2822976	4.282 2976 2976
log. b=4.2965477	•
log. sin A=9.9857499	$A=75^{\circ}\ 24'\ 09''.206$
$\log c = 4.4184219$	
$\log c \sin A = 4.4041718$	4.404 1718 1718
log. sin C=9.94891	9.948 0188 0169
log. α=4.45526	4.456 1530 1549
diff. bet. logs. a=28100	. 60
$C = 62^{\circ} 45''$	62° 31′ 22″ 20″.249
$(ac)\log M \sin 1'' = 8.6766$	3
(ac) log. $\sin A=0.0143$	8.6909
log. sin B=9.824	9.8261
log. sin C=9.948	9.9480
log. diff.=4.448	7 = 1.7782
818"=2.912	7 0.2432=1".751

THE THREE-POINT PROBLEM.

At a point P three stations l, c and r are visible; l is the station farthest to the left, c is the center station, and r is the one farthest to the right, as seen from P. The angle lcr and the distances lc and lr are given.

The angles lPc=L and cPr=R are measured, and it is required to compute the remaining angles clP=x and crP=y, and the sides Pc, Pl and Pr.

The nomenclature adopted is that generally used in locating buoys, etc., by the three-point problem,

Let
$$\frac{cr}{\sin \mathbf{R}} \times \frac{\sin \mathbf{L}}{cl} = n$$
, (1)

then
$$n \cdot \sin y = \sin x$$
, (2)

and
$$Pc = \frac{cr}{\sin R} \sin y = \frac{\sin x}{\sin L}$$
 (3)

After plotting l, c and r, the point P can be graphically located by some of the usual methods, e.g., by laying down the angles L and R on tracing paper, and then placing this over the plotted positions of l, c and r so that the lines drawn pass through these points respectively. The position of P can then be pricked through the paper.

Next measure clP=x, approximately, and place y=lcr-(L+R+x). Corrections can then be computed to these approximate values until they are as precise as is desirable, then Pc can be readily obtained, and if necessary Pl and Pr.

Example.-

Given
$$lcr=111^{\circ}10'54''$$
 log. $cl=3.797531$
 $L=44^{\circ}09'30''$ log. $cr=3.862668$
 $R=49^{\circ}47'20''$
Measured $x=9^{\circ}$
whence $y=8^{\circ}14'04''$
 $(x+y)=17^{\circ}14'04''$

The value of (x+y) will remain constant, as whatever correction is given to x will be applied to y with an opposite sign.

From (1) first compute n. thus,

$\log cr = 3.862668$ $\log \sin R = 9.882906$	log. sin L=9 843011 log. cl=3 797531	
$\frac{cr}{\sin R} = 3.979762$	$\frac{\sin L}{cl} = 6.045480$	

whence log. n=0.025242.

1st Approximation.

$$y=8^{\circ}14'04''.\log. \sin=9.155016....9.1550$$

$$y=9^{\circ} \qquad \log. \sin=9.194332....9.1943$$

$$14074 \log. =4.1484$$

1st cor. = 504'' . . 2.7026

(ac) \log , M. $\sin 1'' = 9.6766$. in units of the \log , $\sin (x+y) = 9.4717$ 6th place.

$$\log \frac{1}{\text{M.}\sin 1'' \sin(x+y)} = 0.2049$$

This value of \log . $\frac{1}{M \cdot \sin 1'' \sin (x+y)}$ remains constant throughout the computation, and is used for deducing the 1st, 2d, &c., corrections to the assumed values of x and y.

2d Approximation.	
$\log n = 0.025242$	0.2049
$y=8^{\circ}22'28''.\log.\sin=9.163286$	9.1633
9.188528	
$x=8^{\circ}51'36''.\log.\sin=9.187579$.	9.1876
949 lo	g.=2.9773
2d correction=34."1.	1.5331
3d Approximation.	- 1
$\log n = 0.025242$	0.2049
$y=8^{\circ}21'53''.9.\log.\sin=9.162798$	9.1628
9.188040	
$x=8^{\circ}52'10''.1.\log.\sin=9.188039$	9.1880
1 lo	g = 0.0000

3d correction=0".04 8.5557 The values of y and x are now suffi-made above, will check the work.

ciently precise, and from (3) we obtain Pc directly.

If Pl and Pr are desired they can be computed from the formulae,

$$Pl = \frac{cl. \sin Pcl}{\sin L}$$
 $Pr = \frac{cr. \sin Pcr}{\sin R}$

The results obtained are very well checked throughout. If care is taken in computing n no subsequent error need be feared, for the computation of Pc, as

EXPERIMENTS ON THE EFFICIENCY OF INCANDESCENT ELECTRIC LAMPS.

BY HORACE B. GALE.

Contributed to Van Nostrand's Engineering Magazine.

the Massachusetts Institute of Technology, and furnished the material for a thesis, from which what follows is selected for publication.

The object of the tests was to ascertain the efficiency of each of the principal forms of incandescent lamps when run at various candle powers. The efficiency, as the term is here employed, is measured by the number of candle lights produced per horse power of electrical energy expended in the lamps them-

As much of the work as possible, including the calibration of the instruments used, was done in the laboratories of the Institute. The other experiments were made at one of the lighting stations of the New England Western Electric Light Company in Boston, as the necessary dynamo power could be more readily obtained there than elsewhere. It should be stated, however, that this

These experiments were made by the company had no part in the experiments, writer in April and May, 1883, when a and no knowledge of the results, except student in Mechanical Engineering at what was gained afterwards by inspection of the diagrams presented herewith. The forms of lamp tested were the Maxim, the Edison, and the Bernstein. Measurements of the Swan lamp, which it was intended also to include, had to be omitted on account of the limited time which could be spared for the work.

Before describing the experiments, a few words may be devoted to the

GENERAL PRINCIPLES

which govern the efficiency of an incandescent lamp. Each of the lamps mentioned consists essentially of a filament of carbon inclosed in a glass globe, from which the air has been exhausted; the ends of the filament being joined to two platinum wires, which pass through, and are sealed into the glass. These wires form the connections by means of which a current of electricity is sent through the carbon. The energy which must be expended to force the electricity through the resisting substance of the filament is transformed into heat, which shows itself by raising the carbon to incandescence.

The heat escapes from the carbon filament in three ways: first, a little is conducted away by the connecting wires; second, a still smaller amount, probably, is transferred to the glass by the rarefied gas left in the globe; third, the remainder, which represents practically the whole energy expended in the lamp, escapes from the carbon by radiation. This radiation consists partly of invisible heat, and partly of light; and it is clear that the most efficient lamp is the one in which the largest part of the radiant energy is in the desirable form of light. In other words, the efficiency of an incandescent lamp depends solely upon the proportion between the quantity of energy which is given off as light, and that which is wasted as invisible heat.

Now the ratio between the quantity of light radiated and the quantity of heat radiated by any solid body, depends upon its temperature. The shape or structure of a body, or the extent of its surface, though influencing the total amount of radiation, cannot affect the proportion of the light and the heat.

By adjusting the strength of the current passing through the carbon of an incandescent lamp, we may heat it as hot as we please. We may raise it to a moderately high temperature without getting any light at all, all the energy expended being wasted in the form of heat; increase the quantity of electricity passing through the filament, and we can bring it to a dull red; again augment the current, and it glows with a feeble yellow light; and now, if the current is made a little stronger, without adding much to the amount of heat radiated, the intensity of the *light* becomes enormously The way in which the candle increased. power rises, as the current strength is augmented, may be seen in the following table, based on a series of measurements made upon a Maxim "B lamp," designed to give about nine candle power.

The efficiency of a lamp, that is, the return we get in light for a given amount of electrical energy, being greater the higher the degree of incandescence to which the carbon is brought, it follows from paper, cut with a die to a shape

Current strength in am- peres.	Candle power.	Increments of current strength.	Increments of candle power.
$egin{array}{c} 0. \ 0.5 \ 1.0 \ 1.5 \ 2.0 \ 2.5 \ 3.0 \ \end{array}$	0. 0. (very dull red). 3.5 17.0 55.0 -120.0	0.5 0.5 0.5 0.5 0.5 0.5	0. 0. 3.5 13.5 38.0 65.0

tain limits, make its efficiency as high, or as low, as we choose. On the other hand, the hotter the carbon is heated, the sooner it is disintegrated and destroyed. A gradual transfer of particles of carbon takes place from the filament to the inner surface of the glass globe; the latter becomes darkened, the resistance of the carbon is raised, and finally the filament breaks at its weakest point.

It is worth noting in this connection, that in the experiment referred to above, the Maxim lamp was run for about fifteen minutes at more than ten times its normal candle power without apparent injury, a fact which speaks well for the endurance of this form of lamp.

While the efficiency of an incandescent lamp is thus a matter of temperature, chiefly, being greater the higher the temperature, its durability depends both upon the temperature and upon the form, structure, and density of the carbon, as well as upon the perfection of the vacuum obtained in the globe. The relative economical importance of the efficiency and the durability of a lamp will vary, of course, in different circumstances, according as the cost of the power, or the cost of renewing the lamp, is the greater; and if we can discover the law connecting the efficiency, length of life, and candle power of a given form of lamp, we can determine, for each special case, at what candle power the lamps should be run in order to obtain the greatest economy.

DESCRIPTION OF LAMPS.

The peculiarities of the various types of incandescent lamps depend mainly upon differences in the carbon filament.

The carbon of the Maxim lamp is made that by varying the candle power of any somewhat like a letter M with its angles incandescent lamp, we may, within cer- rounded. After carbonization, the filaof hydro-carbon vapor, and heated by the current. The vapor is decomposed, and its carbon is precipitated upon the filament in such a way as to obliterate all inequalities in it.

Three styles of Maxim lamp were used in these experiments, rated respectively as 12, 24, and 16 candle power. They were obtained at the Stanhope Street electric light station in Boston, and were taken at random by the writer from a large stock on hand at that place.

The carbon of the Edison lamp is a long, fine filament, made from Japanese bamboo wood, cut to the requisite size in a gauge, and bent into the shape of a U. Three varieties of Edison lamps were experimented upon, rated as 8, 10, and 16 candle power. These lamps were sent from the factory of the Edison Company at Newark.

The Bernstein lamps used in these tests were peculiar in many respects, perhaps the most striking peculiarity being their very low resistance. carbon consisted of a straight hollow tube, about an inch and a quarter long, of the size of a straw, and terminated by two knobs or bulbs of carbon about a quarter of an inch in diameter, into which the ends of the connecting wires entered. These lamps were obtained by the writer from the factory in Boston. They were rated at 30 candle power. As they had scarcely passed their experi-mental stage, and have since been improved, the results obtained from them are not presented here as fully as are those obtained from the Edison and Maxim lamps.

RESISTANCE COLD.

The following table shows the resistance of the various lamps when cold. resistance, made by Elliott Brothers, ities of the two lights at the two ends

ment is placed in a rarefied atmosphere London. It was mounted on a pier of masonry, and furnished with a compensating magnet and shunt coils, so that it could be made as sensitive as desired.

RESISTANCE OF EDISON LAMPS, COLD. (Temperature of room, 68°).

10 candle lamps.	8 candle lamps.	16 candle lamps.	
Ohms. No. 21, 380.0 " 22, 377.5 " 23, " 24, 384.0 " 25, 396.8	Ohms. No. 16, 125.0 '' 17, 111.0 '' 18, 114.0 '' 19, 107.0 '' 20, 108.5	Ohms. No. 11, 300.0 '' 12, 300.0 '' 13, 291.0 '' 14, 268.0 '' 15, 297.5	
Average,384.58	Average,113.10	Average,291.30	

RESISTANCE OF MAXIM LAMPS, COLD.

24 candle (A) lamps.	B-lamps.	16 candle lamps.
Ohms. No. 1, 75 0 " 2, 74.6 " 3, 74.4 " 4, 76.0 " 5, 75.4	Ohms. No. 30, 34.0 '' 31, 32.2 '' 32, 34.7 '' 33, 35.0 '' 34, 34.3	Ohms. No. 41, 148.3 '' 42, 149.2 '' 43, 148.3 '' 44, 150.0 '' 45, 153.4
Average, 75.08	Average, 34.04	Average, 149.84

RESISTANCE OF BERNSTEIN LAMPS, COLD.

30 candle lamps.			
No.	1	.4.37	Ohms.
4.6	2	.6.47	6.6
	3.'		" "
6.6	4	.1.42	"
6.6	5		
	· · · · · · · · · · · · · · · · · · ·	·	
Ave	erace	.3.52	6.6

THE PHOTOMETER.

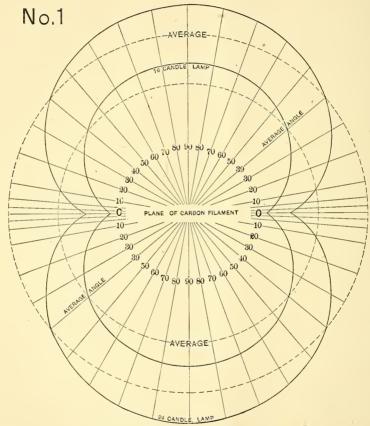
The measurements of candle power The numbers here given were marked were made upon a photometer of the on the bases of the individual lamps to ordinary Bunsen type, having a bar 100 indentify them. The resistances were inches long. The disk was inclosed in a measured with a large new Wheatstone's box about a foot long, having an opening bridge made by Williams of Boston, which was used as a standard of resistances throughout the work. Before using disk could be viewed at once from an it, the coils were tested by comparison opening in front. The box carrying the with those in the Physical Laboratory at disk could be rolled on wheels along a Harvard College. The galvanometer horizontal track, and a pointer projecting used in the bridge was a Thomson double downward opposite the disk indicated on coil reflecting instrument of 5,000 ohms- a graduated scale the ratio of the intensof the bar. The whole was placed in a dark room, the interior of the room, and also the apparatus itself, being painted a dull black.

ILLUMINATION AT DIFFERENT ANGLES.

On account of the shape of the carbon filament, incandescent lamps generally give more light in certain directions than in others; and it is important to know

then turned about its vertical through ten degrees, or less, at a time, as indicated on a graduated circle, and the intensity of the light given off at each angle was compared with that of the other lamp, which remained fixed, and served as a standard.

The principal advantage of this method is, that if any accidental variation in the current should cause the candle exactly what the variation is, so that we power of the lamp tested to vary slightly



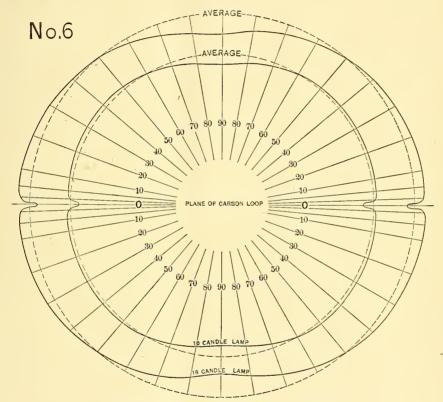
CURVES OF EQUAL ILLUMINATION. (IN HORIZONTAL PLANE.)

may calculate, from a single measurement from its normal value, the brightness of the lamps. through both. One of the lamps was scribed further on.

of the intensity of the light in a given the standard lamp will vary in the same direction, what is the true average candle way, so that the ratio of the candle power of the lamp. This point was ac-powers will not be affected. It was found cordingly investigated for each one of that in this way these experiments could The method used was to be carried on equally well with a current place two lamps of the same kind, con- of variable intensity as with a steady nected either in series or in multiple arc, current. In all the tests here described, at opposite ends of the photometer bar, however, the current was kept perfectly and send a current from the same source steady, by a method which will be de-

found. its plane) was computed for each lamp, center, the plane of the carbon filament

The values of the illumination of each curve represents the illumination of the lamp at the different angles were laid old style, or 24 candle-power, Maxim off graphically from a center, and a lamp; and the inner curve that of the curve drawn through the points thus Maxim lamp as improved by Mr. Weston, The area of each curve was which is the style at present made by then measured with a planimeter, and the United States Electric Lighting the ratio of the true candle power to the candle power as measured on the face of the carbon loop (i. e., perpendicularly to



CURVES OF EQUAL ILLUMINATION. (IN HORIZONTAL PLANE.)

by diagrams No. 1 and No. 6.

made only in a horizontal plane, because face, or flat, of the carbon is considerably that is the usual method of measuring candle power, though perhaps a fairer comparison of the different lamps would edge (marked 0) round to the face, is be arrived at by taking the average extremely regular for the Maxim lamps, spherical illumination.

Referring to diagram No 1, the outer almost identical.

The average results for each class of being represented by the line 0-0, all lamps were also plotted in the same way. points on the curve will be equally il-The forms of the curves obtained, for luminated. The carbon of the Maxim the Maxim and Edison lamps, are shown lamp, being made from paper, is several times as broad as it is thick; hence we The photometric measurements were see that the illumination opposite the greater than that on the edge. variation in brilliancy, as we go from the the curves of the individual lamps being

Diagram No. 6 shows the same thing however, it was found possible to mainfor the Edison lamps. Here the carbon tain a current of a perfectly uniform infilament has its greatest breadth in tensity for any desired time. The batplane of the loop, so that the illuminaas we go toward the edge. Just in the plane of the loop, however, there is a lamps. The current passing through the sudden falling off in the intensity of the lamps could be regulated by means of U are exactly in line, one cuts off the the number of cells of the battery in cirlight of the other. Though these curves, each showing the average of five lamps, are tolerably regular, the curves for the indvidual Edison lamps are quite irregular, owing to the carbon being more or less twisted.

The illumination of the Swan lamp, one of which was tested at this time, was found to be the most uniform, being practically the same in all directions. is claimed, however, that a uniform illumination is not always an advantage, as it is often desirable to be able to throw more light in certain directions than in others.

In each of the diagrams a circle is drawn, whose area is equal to the area of the irregular figure bounded by the curve of equal illumination, and the intersection of the circle with that curve gives us the angle at which we should measure the light of the lamp in order to get its true average candle power. better way, however, and that here adopted, is to measure the candle power of each lamp on the face, and compute its average candle power by referring to the curve for that individual lamp.

SOURCE OF CURRENT.

For experimenting upon incandescent lamps, it is desirable to be able to maintain, for any length of time, a perfectly uniform and steady current of electricity. The available sources of current were in this case a Weston fifteen arc light dynamo machine, having the field in derived circuit, and a Kabath secondary battery of seventy-two cells. The current of the dynamo machine, though tolerably steady, was not perfectly so, on account of slight variations in the speed; and that from the storage batteries, though not subject to fluctuations, would

direction perpendicular to the teries were connected in series, so that any number of them might be placed in tion is feeblest on the face, and increases the circuit of the dynamo machine, in derivation with the loop supplying the light; because when the two arms of the an adjustable resistance, or by varying cuit; and a variable resistance was also interposed in the field circuit of the dynamo, so that its electromotive force could be adjusted to just balance that of the battery. The dynamo thus supplied the current to the lamps without exhausting the battery, which merely served to keep the electromotive force on the lamps constant, and absorb any fluctuations that might exist in the current of When the lamps were the dynamo. turned off, the dynamo merely supplied the loss due to leakage and local action in the cells. This arrangement of balanced electromotive forces is, of course, not possible with a dynamo having the field coils in direct circuit.

THE MEASUREMENTS OF CURRENT

were made by means of one of Ayrton and Perry's ammeters, which was carefully calibrated at intervals during the progress of the tests by comparison with a tangent galvanometer. The constant of this galvanometer was computed from the number and diameter of the coils, and the value of the horizontal component of the earth's magnetism as determined at Cambridge, and was also ascertained directly by the electrolysis of a solution of pure sulphate of copper. The results of the two methods were found to differ by less than one per cent.

DETERMINATION OF GALVANOMETER CON-STANT.

In the determination by the deposition of copper, three large Daniell's cells, whose joint resistance in parallel circuit was about .08 of an ohm, were used as a source of current; the circuit was completed through the galvanometer, a resistance box, and a depositing cell with a copper anode and a platinum cathode, nevertheless run down gradually as the the liquid being a saturated solution of cells became discharged. By using the chemically pure sulphate of copper. The machine and the battery in combination, resistance was first adjusted to obtain a a little more than 30°. The platinum the strength of the permanent magnet cathode was then removed from the cell, washed with distilled water and alcohol, dried, and weighed. The circuit was again closed by lowering the cathode into the solution, and the deflection of the galvanometer was kept constant for about an hour and a half, when the circuit was broken by taking out the cathode, which was washed, dried, and weighed, as be-The data for calculating the galvanometer constant were as follows:

Increase in weight of the cathode. 0.22208 gram. Time during which the current

Tangent of deflection......0.6918.

Assuming that one ampere of current deposits .00033 gram of copper per second, as given by Prof. S. P. Thompson in his "Electricity and Magnetism," we have.

$$C = \frac{0.22208}{5095. \times .00033} = 0.132$$
 ampere.

Hence the galvanometer constant

$$=\frac{0.132}{.6918}=0.19.$$

The galvanometer had 36 coils, whose mean diameter was 52 centimeters. Computing from these data the value of the horizontal component of the earth's magnetism, we obtain H=0.165. The value of H, as determined at Cambridge in 1882, was 0.164.

CALIBRATION OF AMMETER.

To calibrate the ammeter, it was put in circuit with the Daniell's battery, a resistance box, and the galvanometer, the current being divided between the latter and a shunt of No. 12 copper wire. multiplying power of this shunt was 13.29. By adjusting the resistance the reading of the ammeter was varied by one degree at a time from 0° to 22°, deflections being taken both to the right and left, and simultaneous readings made of the galvanometer. The deflec tion of the ammeter was found to be proportional to the current, as far as the test could be carried, after making correction for a permanent displacement of the zero point of 0.14°, which was allowed for in all the subsequent work. The ammeter was again calibrated near the middle, and again at the close of the

deflection of the galvanometer needle of the first calibration; thus showing that had not altered perceptibly while the work was in progress.

SECOND SERIES OF TESTS.

The object of the next series of observations was to obtain the data from which curves could be constructed for each lamp, showing the variation in candle-power and current strength as the electromotive force is increased. The method consisted in varying the candle power of each lamp by a succession of steps, from zero to as high a point as it could safely be carried, and taking simultaneous measurements of the electromotive force, current, and candle power at every point.

DETERMINATION OF ELECTROMOTIVE FORCE.

The current passing through the lamp could be ascertained directly by means of the ammeter; but the resistance of the lamp when hot being unknown, to find the electromotive force it was necessary to place the lamp in derivation with a coil of wire of known resistance, and measure at the same time the current passing through this coil. The electromotive force was then found by multiplying together the values of the currentand resistance.

L ONGITUDE BY TELEGRAPH.—The difference of longitude between Buenos Ayres and Valparaiso has been determined by telegraph by M. Beuf, Director of the Naval School of the Argentine Republic; so also has the difference between Valparaiso and Panama, between Valparaiso, Callao and Lima, between Santiago and Valparaiso, and between Santiago and Cerro-Negro. Various French naval officers have undertaken these last determinations. A full account of the operations, by means of the various submarine cables and telegraph wires connecting these places, has been communicated to the French Academy of Science by M. de Bernardieres, Naval Lieutenant, who, in conjunction with M. Beuf, made the Buenos Ayres to Valparaiso, that is to say, the main Transcontinental determination. The result shows that the difference of longitude between the flagstaff of the Bourse of Valparaiso and the Cupola of the Custom House at Buenos Ayres is 63 min. 4.230 sec. The longitude of Ayres is 63 min. 4.230 sec. The longitude of the flagstaff of Valparaiso Bourse is 4 h. 55 min. 45.11 sec. The latitude of the same spot is given as 33 h. 2 min. 10.1 sec. The latitude of Buenos Ayres (the cupola of the Custom House) is given as 34 h. 36 min. 27.7 sec. The Americans previously measured it by Talcott's. experiments, the results agreeing with method, and found it 34 h. 36 min. 29.8 sec.

THE BEHAVIOR OF ARMOR OF DIFFERENT KINDS UNDER FIRE.

BY CAPTAIN ORDE BROWNE, R. A.

From "Iron."

which bring out the characteristic behavior of the principal kinds of armor under the impact of shot, and then to point out the necessity for recognizing that the mechanical conditions of one case may be so entirely different from those of another as to call for different qualities in the shot, and a totally different system of calculating effects. The importance of this question will be apparent if it is borne in mind that there are four principal kinds of armor employed by European powers. The natural tendency is for us to test our own shot and armor against one another. The important matter, however, is to know the behavior of our shot against the particular kind of armor that our enemy may have, not against our own. It appears, perhaps, like killing two birds with one stone if we prove our shot against our own armor. The advantage of such an achievement, however, is lost if one bird is a wrong one, and this may in a certain measure be the case if we continually follow the above course in the face of the adoption of the armor by foreign powers differing widely from our own in its nature. The four kinds of armor to which I refer are as follows:-

- 1. Wrought iron.
- 2. Wrought iron with a steel face (termed compound armor).
 - 3. Solid steel; and,
 - 4. Chilled cast iron.

I will first specify, as far as I am able, the characteristic behavior of each under impact, in order that, when I come to them, you may see how far the experiments I notice bear out what is said; and I would observe that these experiments are simply the most important recent ones, and cannot be said to be specially selected.

The object of this paper is to notice made in it. The rest of the target hardly briefly the features in recent experiments suffers appreciably, except close to the point of impact. The entire shield, including bolts, is generally capable of resisting any subsequent blow as stoutly as it resisted the first one. Effect here must be obviously produced by the bare power of perforation of each round taken singly. Partial perforation is practically useless, however often it may be repeated. The shot experiences but little resistance as its point enters, and hence it is well enclosed and supported round its head before the full strain comes on it. Hardness and rigidity of metal in the projectile here tell to the greatest extent, and tenacity to the least. Need I add that these conditions have favored the use of Palliser's chilled iron shot with sharp points? The plate yields at the back opposite to the point of impact by tearing in a cross or star line, letting the point of the shot through the center.

2. Steel-faced wrought iron (Cammell's, made on Wilson's patent; or Brown's, on Ellis's patent).—Here the steel face which constitutes about one-third of the thickness of the plate, is a harder class of steel than is generally supposed,* and resists the point of the shot abruptly, and severly tries the tenacity of its metal. It is seldom, indeed, that a projectile holds together under these conditions; there is a mechanical force acting something like the outward thrust on the sides of an arch, and the shot sets up, or more commonly breaks to pieces, leaving but little metal lodged in the plate. The plate yields mainly by cracking in radiating lines from the point of impact. In plates badly backed the plate bends slightly back, and very rigid shot occasionally get their points through; but when well backed, the entire plate must be broken in pieces and displaced before a shot gets past it in any

^{1.} Wrought iron yields locally; it is punched or perforated, a clean hole being per cent., and Schneider's solid steel plate about 0.45 per cent. and Schneider's solid steel plate about 0.45 per cent. of carbon.

sense. In addition to the radial cranks, concentric ones are apt to be developed, sometimes, I think, owing to the tendency of the plate to give back about the point of impact.* Obviously, here tenacity in the shot is called for in a much greater

degree than with wrought iron.

3. Solid steel; as made by Schneider and used in many foreign ships, though rather less hard than the steel face of compound plates, is as a mass more rigid. It admits the points of the shot at first with rather less resistance, but it does not yield at the point of impact even when badly backed, and is, therefore, less dependent on backing than compound As the shot enters, it wedges and heaps up the metal round it, the plate coming forward and swelling at the point of impact and yielding by radiating cracks. I have never known of a concentric crack being made in steel armor, nor of the point of the shot getting through until the plate was stripped off. cracks made are, I think, much more certain to extend through the metal than in the case of compound plates where facecracks may be formed, leaving the iron foundation-plate intact.

4. Chilled iron made by Gruson, and used almost universally in foreign coastarmored defences, is very rigid, indeed. The shot never, I believe, gets its point even a single inch into the metal. The shield transmits the shock through its mass, and must be broken up bodily. Chilled iron is used in large masses, and is best suited to resist single blows, especially in an oblique direction. der the direct blows of heavy shot of high tenacity chilled iron breaks up. Cracks radiating from the point of impact are formed, and the whole shield breaks across. The primary requirement in the shot appears to be tenacity, to enable it to deliver its work on the point of impact before it breaks up, which it does, leav-

The first experiments to notice are two carried out by Krupp at Meppen, in March, 1882. The targets were examples of remarkably successful perforation of wrought iron by steel projectiles. one case a 5.9-inch projectile, striking directly, passed easily through two 7-inch iron plates with 10 inches of wood between, and in the other, striking obliquely at 55°, a similar projectile perforated 7.9 inches of iron, with 9.84 inches of wood and 0.98 inches of iron skin. In the first experiment, which was repeated, both projectiles passed uninjured up the range. In the second, which was also repeated, both the projectiles broke up. I call your attention to the local character of the injury effected on the wrought iron, and the completeness of the perforation, especially when the shot strikes directly.

Next come the Spezia trials of November, 1882, where steel-faced plates 19 inches thick, supplied by Cammell and Brown, competed with 19-inch solid steel supplied by Schneider. Each plate first received a blow from a chilled Gregorini iron projectile weighing 2,000 lbs., fired from a 100-ton gun with sufficient velocity to perforate a wrought-iron plate of 19 inches, that is, about 1,225 feet per second; secondly, a blow from a similar projectile was delivered on each plate, with a velocity of about 1,560 feet, capable of perforating about 25 inches of wrought iron. The steel-faced plates became wholly or nearly detached, and fell from the backing on the second blow. The steel remained up, and received two more blows from steel projectiles.

At the same time was commenced a very similar trial at Ochta, near St. Petersburg, where 12-inch Cammell steel-faced and Schneider steel plates were attacked by an 11-inch gun, firing chilled-iron projectiles with the necessary velocity to perforate 16.3 inches of iron in the first round, and subsequently the necessary velocity to perforate about 12 inches.

It may be seen that at Spezia the French steel plate stood best, but at Ochta the advantage was still more decidedly in favor of the compound plate. Schneider's Spezzia plate was tempered, and was held up by twenty bolts, while Cammell

ing little or no metal lodged in the shield.

^{*}Major O'Callaghan, R.A., Shoeburyness, has contributed a paper to the R.A. Institution, containing a most interesting investigation as to the behavior of steel in steel-faced plates round the point of impact, with his own explanation, and that of Colonel Inglis, of the phenomena exhibited. The original paper should be read by any one who is interested in the matter. Briefly, it may be said that the steel is driven outwards in directions normal to the head of the shot, setting up and buckling as it goes; while the wrought iron yields beneath it, the effect being to produce the separation of the frustrum of a cone of steel from off the face of the target of irregular curved form, with crater-like depressions. It appeared to me that at Spezia the comparatively soft Gregorini shot-points were moulded into a form originated by this action.

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which plates could not be tempered, be- shot. cause the plates are curved. This placed the steel-faced plates at a disadvantage, with a 9-inch gun, 29 calibres long, drove and the Italian officers consider that the a forged steel shell, weighing 403 lbs., yielding character of the backing told through an 18-inch wrought-iron plate, against the steel-faced plates, which would be much more rigidly supported feet. The projectile had a good deal of on the ship's sine. The fall of the fragments makes the difference between the English and French plates appear greater through an oak backing and steel skin than it was. There the tendency of the steel-faced plates was to give backwards, and the steel to swell at the point of these last experiments the work is strictly fracture is concentric as well as radial.

On August 22, 1883, was commenced 4-inch plate. a remarkable experiment at Shoeburygranite. The iron consisted of two 8tween, and the steel-faced plate was 12 24 inches of wrought iron. cut a clean hole through the iron, breaklodging in the plate, cracking and bend- fragments. plate. This last result is an extraordinary one, the plate, when thus well-supported, having borne a blow capable of perforating 24 inches of iron, and containing under these conditions. There is hardly a case of eccentric cracking. In usual clean perforation.

Three other experiments on perforation deserve notice. Captain Palliser, with a shot whose calculated perforation must not, of course, compare this with is about 7.7 inches, completely perforated Gruson's shield, because, being backed a wrought-iron plate 8.73 inches thick with granite, the plate only represents a on April 5, 1883, with a special pointed portion of the shield, but it is easy to see steel-jacketed shot of reduced diameter; that it held together under a vast blow. and what, perhaps, deserves more notice, The work on the Gruson shield was on June 6, 1882, he perforated complete-delivered in three blows and distribly a 4-inch steel-faced plate with a 13- uted. The Gruson shield was broken

and Brown's had only six bolts each. a striking velocity of 1,550 feet, and These makers object to the tempering of a calculated perforation of 4.6 inches of the steel, urging that their plates were wrought-iron. He also perforated a 6samples of their supply to the Italia, for inch steel-faced plate with an 80-pounder

> In August last, Sir Joseph Whitworth, with a striking velocity of about 1,900 work left in it, smashing up a very heavy cast-iron supporting plate, and passing and many feet of wet sand. The projectile is a most remarkable one. In all In the steel-faced plates the local, especially deserving notice on this account in the case of the steel-faced

Finally, I would mention an experiness on the resisting power of plates of ment of a totally different character, iron and steel-faced plates fastened on namely, one conducted at Buckau, Magdeburg, by Gruson, on October 22, 1883, inch plates, with 5 inches of wood be- when a chilled-iron shield with a maximum thickness of 43 inches, weighing inches thick. The 80-ton gun was fired $47\frac{1}{2}$ tons, was attacked by a 12-inch at these with a projectile of chilled iron Krupp gun (30.5 c.m.), firing a steel proweighing 1,700 lbs., with a velocity of jectile weighing about 980 lbs., with a nearly 1,600 feet, capable of perforating striking velocity of about 1,460 feet, and The shot having an energy, therefore of about 14,500 foot-tons. After three rounds the ing up, but penetrating nearly 10 feet shield was cracked or broken across in into the granite. Against the steel-faced more than one direction, and a fourth (Cammell's) plate it broke up, the head shot began the actual displacement of the There was nothing here of ing, but not breaking or detaching the the nature of penetration, the surface only at the points of impact being chipped off. Considering the destruction as effected by the shock on the mass of metal it may be in a sense measured by ing about 30,000 foot-tons energy, showing the energy per ton of shield; this what steel-faced iron is capable of enduramounts to 916 foot-tons in the whole three blows.

The steel-faced plate on granite at the case of the wrought iron there is the Shoeburyness weighed about $10\frac{1}{2}$ tons, It received a blow of a probably. shot with 30,000 foot-tons energy, or about 2,857 tons per ton of metal. We pounder shot of his special pattern, with up; our Shoeburyness one was not, but

there would have been a better chance of completely dividing it if a steel shot had This would have held been employed. better together, and perhaps set up, following the opening parts of the plate, instead of a rigid chilled iron shot shivering directly it began to lose its form. My object, however is not so much to make a comparison of the total resisting power of the different classes of armor as to indicate the shape in which the work has to be done, and the consequent mechanical bearings of the question. think it will be clear to all present that in the case of wrought iron we have simply to deal with perforation. In the first days of the Plate Committee Sir William Fairbairn suggested an equation for the calculation of this work, which with slight modification, answers very well to the present day. Indeed it happens to require less empirical correction with the present guns firing long projectiles at high velocities than those employed in early days. This equation is simply,

$$\frac{\mathbf{W}v^2}{2g} = \pi \mathbf{D}t^2 k,$$

where W equals the weight of shot, D the diameter of shot or hole made, v the striking velocity of the force of gravity, t the thickness of plate perforated, and k a constant to be determined practically. The equation consists in putting the total energy or stored-up work in the shot at the moment of impact equal to the work performed on the plate. The left-hand side is absolutely true, and the righthand side can be shown to be correct in a measure; the only term that is empirical to the full extent is t^2 ; but under the most important conditions it happens to be most nearly correct. The formula does not apply to cases of partial penetration; but as partial penetration is useless, it really gives us all we need for wrought iron.

To pass on to other cases, we may now and then, in compound plates, get actual perforation, or we may get an instance when a steel shot sets up and drives a disc out of a compound plate, which action may partake of the nature of perforation. With most compound plates, and all solid steel, however, you will ob-

have only fracture caused by a blow delivered by an ogival-pointed wedge. It differs wholly from perforation; for while in both cases the stored up work or energy is the motive power in perforation, the thickness perforated depends inversely on the size of the hole or diameter of the shot; whereas in destruction by fracture the point only of the shot enters the plate, and its diameter can scarcely enter into the question. We may suppose, when all other conditions are the same, fracture effected on any given plate may be simply proportional to the stored-up work; but this fact is of little use to us, for other conditions will very seldom be the same as that of some known example. We want to be able to calculate for varying dimensions of plate and velocity and weight of shot, and this at present we cannot do. general method of matching a shot against a steel-faced or steel plate is to give the shot sufficient striking energy to perforate wrought iron of the same thickness, or else of 20 per cent. more thickness than the compound or steel plate attacked. This has been the method followed at Shoeburyness, at Spezia, and at St. Petersburg. In each case, the power of the shot to injure armor, which you observe was destroyed by fracture, was calculated on the basis of perforation. It is easy to show that this a totally false principle. Surely armor ought to be divided into two distinct classes, which we may term "soft" and "hard," the former signifying armor which is perforated, and the latter, armor which refuses to yield in this way, and must be broken I have tried to illustrate the difference by means of a "dropping apparatus" or "pile-driving machine," which the director of artillery kindly allowed me to have made in the arsenal. There is a weight into which punches, representing ogival shot of different sizes, can be fixed. It would be wrong to assume that results obtained by such insignificant forces necessarily represent what occurs in firing at armor; but we may illustrate principles thus, if it turns out, as it does, that the results here obtained are nearly in accordance with the formula which is proved to be correct, and is in use for serve that the plates are destroyed by problems in armor-piercing. Indeed, I fracture, the shot's point penetrating to got the machine made, feeling confident an insignificant depth. Here, then, we that this would be the case. Wrought iron is represented by millboard slabs, and hard armor by hard brick. The perforations in the millboard slabs are so like those made in iron plates that a photograph of one might almost be mistaken for the other. The hard brick so far resembles hard armor that the point of the shot-punch enters a very short distance before fracture occurs. To test Fairbairn's equation, $\frac{Wv^2}{2g} = \pi Dt^2 k$; as the velocity is here due to a fall, we may substitute WH (weight into height) for the stored-up work $\frac{Wv^2}{2q}$ and write WH $=\pi Dt^2k$.

Nothing can well be more simple than this, and you can see that it is fairly carried out, as you can see the height from which the weight drops. It is easy to take one pair of terms and test how one affects the other, leaving all the other terms constant. Here, to bring out my point, I change the diameter and try its effect on H, the height of fall. double the D, obviously if the W is kept unaltered I must double the H. Multi-H by 4. Thus the \frac{1}{4}-inch shot punch at 10 inches fall should perforate the same fall, and the inch punch with 40 inches At the lowest heights there is observe, perforates this slab at 60 inches, the latter only requires to make a small hole compared with the former. Observe, then, as to the thickness perforated, the 4-inch punch at 17 inches is absolutely equal to the inch at 60 inches. So much for perforation; now for smashing hard with the same weight behind it requires four times the fall. You see it is about this show what a totally wrong principle is difficult to investigate. Clearly the is followed at Shoeburyness, at St. Petersburgh, and at Spezia, when the shot is matched against hard armor on the data for perforation? I do not mean that burgh, and at Spezia, when the shot is

results which are grossly wrong are obtained. I have taken extreme conditions to bring out the error palpably, but this error certainly exists in a degree.* It is much easier, however, to find fault than to suggest a remedy. How can hard armor be dealt with? I have been in the habit, when writing in the Engineer, of trying to measure the shock against hard armor by the energy per ton of shield, and only learned recently that Gruson employs the same measure. Nevertheless, while it is of some use as a check on the perforation figure, it is itself just as wrong in theory. It is quite clear that there must be some limit as to the distance of the mass we thus deal with from the point of impact. If I strike a long narrow plate near one end, surely it will snap across. The length is immaterial here, and I shall get nearly the same results with two plates, one double the length and weight of the other, and therefore receiving only half the shock per ton. We must not, then, blindly take the whole weight of each plate as the basis of calculation.

The results of fracture constitute so ply the D by 4, and I must multiply the difficult a problem that it has been said that it has nothing to say to mathematical calculation. This, however, you will, slab as the 1-inch punch with 20 inches I think, not concede. Surely the line of least resistance must be subject to mechanical laws, however hard to discover. some irregularity, but still this is ap- Even steel itself, though we may be proximately true; the inch punch, you tempted to think so, is not really capricious, but is bound to follow certain laws. and the 4-inch at 18 inches fall, because In this question we have no doubt diffi-As to dimensions, we cult elements. have probably primarily to consider the minimum cross measurement as one lineof probable fracture, but you will see that from various causes the plate does not always so yield; bolt-holes and other The 4-inch punch breaks the elements may have their influence. Still, brick slab at 10 inches fall. Now, no one while not a guide as to actual direction, here can suppose that the inch punch the minimum cross measurement may help as to amount of resistance. On the other hand, an increase in the maximum equal to it with an equal fall. For per-direction or length of a plate is held foration, then, the energies required, are rather to facilitate cross fracture just as in the proportion of nearly four to one; a long stick is more easily broken than a for smashing they are equal. Does not short one. The actual work of cracking

more work than the completion of it, consequently an increase in width of plate would most probably not give a plate a proportional increase in resisting power. Such a question as this could only be invegtigated by a very extended series of be exhibited in a measure against other experiments. I would, however, venture to suggest that much might be done on a very small scale. I understand Mr. Whinfield to say that Sir Joseph Whitworth has found that experiments with bullets represent generally the conditions of similar ones with ordnance. I should think, then, that much might be learned by firing steel bullets against a series of small plates of steel and chilled iron, always keeping all conditions uniform, of investigation; comparisons being made as far as possible with such results of experiments with ordnance as we possess. Be this as it may, is it not obvious that at the present moment all nations are in want of experiments made with a view to determine the conditions of fracture of

hard armor under impact?

In England we need trials against the hardest classes of armor, that is, solid steel-faced armor, may tend to develop hardness in our shot at the expense of the tenacity that is needed for the hardest classes of foreign armor. These two classes—solid steel and chilled iron—we ought to have specially in view, because many of the ships which most concern us carry steel, namely, the Admiral Duperre and most French ships, as well as the Duilio and Dandolo, while nearly all foreign coast forts have chilled iron armor. Chilled iron had been adopted for inland forts as well as coast defences in France, owing to its power to resist chilled shot; but in 1882 steel projectiles were tried against it, and produced such effect that chilled iron was then condemned for inland works, which, it may be observed, are liable to be exposed to more prolonged and systematic fire than coast forts. Should we unfortunately retain our chilled shot after foreign powers adopt steel, the above verdict in France would imply that chilled iron forts are good enough to resist English shot, but not those of other nations. At Meppen, in 1879, chilled shot failed tain Orde Browne said that the heavier

first portion of a crack represents much against a chilled iron shield, and had to be replaced by steel projectiles. If it be urged that the attack of armored coast forts is an exceptional and undesirable operation, it must surely be admitted that the weakness here brought out must hard structures, and is surely a matter to investigate. Last year a commission was sent over from America to investigate the condition of iron and steel in Europe. It is said that the report speaks unfavorably of English steel. This is to be understood if it refer to our steel projectiles, which seem specially to need encourage.

ment at the present time.

Captain Mackinlay, R.A., referring to a remark of Captain Orde Browne's, said except those whose relation is the object he had brought out in a very clear manner the different behavior of steel or compound armor and of wrought iron alone, when struck by a projectile. With the old system of wrought iron it was easy to tell beforehand what might be effected by a given projectile, striking with a given velocity; but experiments with the modern kind of armor showed that the estimation of probable results beforehand was not an easy matter. Mention had steel and chilled iron; otherwise, our been made of a steel-faced plate at Shoesuccess in perforating iron, and even buryness, the resisting power of which was very good, and from the absence of concentric cracks it would appear that that plate had been only slightly deformed, and had been kept in its place by the rigid backing behind it. Contrasting with this the behavior of the compound plates at Spezia, which broke up, it would appear that where the target itself was able to give way considerably, such a plate would be likely to break up. Therefore no estimation of the probable resisting power of any new plate could be well arrived at without a careful consideration The frame holding of the backing. experimental targets was not generally nearly so rigid as that which would contain it on an actual fortification or on a ship. Coast forts might have an advantage over ships, for the reason that it was easy to give a rigid backing to armor on a fort, where weight was of little account. but it was not so easy in the case of a ship; so that if a plate were struck at some point between the ribs, there would not be so good a result as if it had an even surface of granite behind it. Cap-

the plate, the better was it able to resist worthy of great consideration. better resisting powers than a smaller one, because to a considerable extent it was able to distribute the blow throughout the whole of it. A few years ago an experiment was made on the English coast by firing at a ship's turret, which received two blows, nearly enough to The object of the experipenetrate it. ment was to determine whether the turret could afterwards be revolved, or whether any besides local damage had been inflict-That turret revolved freely after-In the case of the Huascar, in the war between Chili and Peru, the turret could also be revolved after being penetrated several times by 9-inch projectiles. In compound armor the whole effect of the blow was more taken by the whole mass, and it was a question whether turrets made of that new kind of armor would not jam after they were hit. Attention had recently been drawn to this point in the discussion on Colonel Moncrieff's lecture at the Royal United States Service Institution. With regard to armorplates, there are only two manufactories in England, both being in Sheffield. It would be an advantage, from a national point of view, that other makers should take it up, so that there might be several firms to make a large supply of armor if required to meet sudden demands.

why the government had not done more independently of the land artillery, the with regard to steel projectiles. Some years ago he sent for trial half-a-dozen officers, who did nothing but experiment shot and shell made of steel. The Terre Noire Works made shot and shell largely, and why those should be so much more highly prized than shot made in this country he could not understand. Mr. Henry Davey said that it occurred to him that if they could destroy some of the energy of the shot before it was brought on to the actual armorplate, it would be a point of great importance. If one armorplate was put in front of the other, the shot after passing through the first plate would have so much of its energy spent that it would require a less

resisting material behind it.

Mr. Scattergood stated that if Captain the blow; and that seemed to be a point Browne had said nothing more than was With contained in the last five lines of his wrought iron it apparently did not mat- paper, he had shown that it was the duty ter so much what the size of the plate of the manufacturers of iron and steel to was; the chief point was its thickness. do the best they could to retrieve what A large plate of steel appeared to have they appeared to have lost—their good name. Captain Browne had referred to the commission sent from America to investigate the condition of iron and steel in Europe, who had reported, it was said, unfavorably of English steel. He supposed the object of bringing forward the paper was to induce the manufacturers of steel to make better steel than they had hitherto done.

> The President thought he ought not to allow the discussion to proceed without remarking that Captain Browne distinctly stated that the steel was found not to be suitable for a special purpose, though no fault was found with the steel as steel. It was for those gentlemen who conducted experiments like those of which Captain Browne had spoken to tell the steel manufacturers of the country what were the precise qualities of steel required for their purposes. Whenever that was done, English manufacturers would, he had no doubt, produce steel to satisfy the requirements of artillerists.

Mr. Nordenfelt believed the reason why English manufacturers had had so little chance of showing what could be done in projectiles, as well as other things, was that they had so little opportunity of trying what they made. In England there was a school of gunnery, with highly intelligent officers, and the colonel Mr. J. Riley said he had often wondered there had two assistants. But in France, marine artillery kept a staff of sixteen with the manufacturers of the steelmakers of that country. It was a matter of money. The treasury here did not like to ask for the money, and the officers who had charge of the Government factories dared not ask for money, for if they did they would be snubbed. He believed that the experts in charge of these matters in this country went almost further than Captain Browne, in admitting the value of steel, and in admitting that in this country steel had been made by manufacturers which had done quite as much, if not more, than the French steel projectiles.

pleasing duty to record a vote of thanks to Captain Browne for his interesting paper, which opened up many subjects both by chilled projectiles. But he found worthy of the consideration of his profession, as also of the iron and steel ter than he expected, that he took to steel manufacturers of England. Not only iron and steel manufacturers, but the nation also was much indebted to him for having called attention to the serious question of the nature of the projectile mained perfectly sharp. A softer shot which should be prepared for attacking armor of different descriptions. It would formed what was the specific nature of the steel which the Government would in the first instance be willing to test for the purpose to which he had referred. Nothing was better understood than the production of steel of any degree of

out of the question.

regard to what Captain Mackinlay had would always be made hard enough to stop that. The introduction of hard ar-

The President said that it was his wanted to show that his rival's shield was a bad one. He made his rival's shield and his own, and said he would destroy that his rival's shield stood so much betshot, and then in time he broke it up. It was true that a chilled shot going through soft armor would break up, but it would go on and get through, and its front rewas inferior in penetration, but was better for very hard armor, because if both be very desirable that they should be in- shot were abruptly resisted before each shot got the support which it did during penetration, the hard shot would smash to pieces, producing but little effect, and the softer shot would produce more effect, although it also broke up. They were rather running on wrong lines in this tenacity and hardness; all the English country, because they kept on using manufacturers required was to be told armor which did not bring out the full what were the qualities best adapted for value of tenacity in the shot. He had the purpose intended, viz., breaking the never seen chilled iron or steel fired at in armor up; because he supposed that this country except one steel target bepenetration of the hard armor-plates now longing to Sir Joseph Whitworth. Chilled generally adopted here and abroad was iron was fired at many years ago, but it was then in a very embryo condition. He Captain Orde Browne said that with thought it was detrimental to this country that they did not try shot against the stated, he wished to make it clear that it very hard armor used abroad. Captain was so intolerable to have a hole made in Mackinlay had called attention to the a shield and to get a shell far through it experiments made against the Glatton so as to explode in the interior, that he turret some years ago, and showed that looked upon it as a certainty that armor however much they could perforate a wrought iron turret, it could afterwards be revolved, and now they had got rather mor was having a greater effect upon smaller bores and higher velocities, the shot than people were aware of. Econoshot would penetrate with less resistance my caused them to try their own shot and less contortion. The whole thing against their own armor, and he had told was, what was the resistance in the act the authorities that they ought not to be of going through? It looked as if a content with trying wrought iron and wrought iron turret would not be affectsteel-faced armor. With the exception of ed because they had shot of greater wrought iron, steel-faced armor was the power of perforation. The shot tired at softest of any, and that was the hardest the Glatton turnet nearly performed the we have in England. Other countries possible work that could be done for the used steel which was harder, and chilled size of the hole it made, and still the turiron which was harder still. These ex- ret worked very well. If they substituted tremely hard kinds of armor called for a hard armor for soft, the work was disdifferent class of projectile to that which tributed through the whole mass, and it had been used in this country. Chilled was more likely to suffer distortion. He shot, which did very well for wrought had seen a steel-faced target at Shoeburyiron, failed against chilled armor. Krupp, ness in which the whole plate was driven in one experiment, wanted to show that back several inches, but they never could a wrought iron shield was better than one of chilled iron. Gruson, a rival of Krupp, manufactured chilled iron, and Krupp because if the shot had sufficient work in

it it might have lifted the entire turret up; nance committee to this. and the reason it did not dislocate the the manufacture of steel shot in the turret was, because the work was local The Inflexible had steelfaced armor, and therefore, as they went or two years ago adopted cast chilled on to harden armor, there might come a time when it might be necessary to try they fired chilled shot, but when once further experiments, such as firing at an they fired steel shot they condemned the armor-plated ship. With regard to double plates the question was a very large one, and some very odd effects had been produce by them. One was that if they had two plates, with a space in between, and fired a chilled shot at them, the shot would foreign nation that adopted steel shot go through a comparatively insignificant front plate, and then on striking the back plate it would fly into fragments. That could not be utilized, because foreign nations did not use chilled shot, and because they might fire a shell which would blow the front plate off. Supposing they had a steel plate capable of keeping out a certain shot, and they put a thin wrought iron plate in front of it, the shot that was before kept out would now go through the iron, steel, and all, for the reason that it was not resisted when its point only touched the shield. If they resisted the shot when its point only was touching, they got an outward thrust and smashed the shot to pieces; but if the shot were allowed to get its head in, it was then supported all round, and would go through. He had stated that the Americans spoke unfavorably of English steel, but he hoped he was not responsible for everything that Americans said. The report was not out yet, but it had been hinted to him that it stated that English steel was in a bad state. could only attribute that to the fact that they had not made steel shot on a large scale, for the reason that the government would not have it, and he did not think the government fully appreciated the position of the question. Steel projectiles were expensive, but they had to prove them against targets, and the targets cost money. If any one made a steel projectile, and sent it to Shoeburyness to be tested, he would only have the opportunity of trying it as far as he had money to spend, at the rate of £4,000 or £5,000 for each shield of iron, and he could not try more than two or three shots at each plate. Then if it turned out badly the

He believed country wanted developing very much indeed. The French a year and a half iron armor, and retained it as long as whole thing. At this moment all English ships carried chilled iron shot, and not steel. The French chilled iron shields then were good enough to resist our chilled shot, but not steel shot; and a would have projectiles much better than our own. Anything that could be done to prove the necessity for the manufacture of steel projectiles in this country would, he believed, be of great service, and that was one of his reasons for bringing forward this paper.

THE CONDUCTIVITY OF COPPER.—The true nature of electrical resistance is by no means well known; and the only light which the induction balance of Professor Hughes has as yet shed upon it has not revealed its true nature. An interesting observation recently made by Mr. W. Groves, the well-known practical electrician of Bolsover Street, W., deserves to be more widely known. Mr. Groves took thin discs of brass and coated them by electro-deposition with a thick layer of pure crystalline copper. He then cut similar discs of copper from the deposit and tested them in the induction balance. The scale gave 200 as their induc-tion value. The same discs, after being melted in a founder's furnace, only gave 100 on the scale, and after a second melting their induction value had fallen to nearly that of ordinary sheet copper, namely from 50 deg. to 80 deg. If, as many believe, the induction value represents the conductivity of the copper, there is here a great falling off, and it might be valuable not only in a theoretical, but a practical sense, to find out the true cause. Dr. Mathiessen found that copper lost in conductivity by absorption of oxygen, and the pure copper being fused in an ordinary founder's furnace may have lost its electric conducting power by absorption of this impurity. Should that prove to be the case there is much to be gained by fusing copper in presence of hydrogen, which, uniting with the oxygen, would form water, and leave the copper in its pure condition. ascertain this it will be necessary to call in the aid of chemistry, and analyze the copper so treated. Mr. Grove's experiment is interesting as opening up a field for further investigation. Should the effect in question not be traceable to the absorption of oxygen it may be due to the molecular structure of the copper in the three cases mentioned, the crystalline structure maker's reputation was staked upon it. He once tried to persuade the ord-

THE TWO MANNERS OF MOTION OF WATER.*

BY PROF. OSBORNE REYNOLDS, F.R.S.

From "Nature."

eral regret with those who are interested case of theory of fluids as in that of in natural philosophy that in spite of solids. The answer is plain enough. As tion fits very ill with the actual behathe assumption of relative internal rest, vior of fluids, and this for unexplained applies to all cases. It is not, however, oretical results agree with those actually laws of motion. obtained, in other cases they are altogether different.

If we take a small body, such as a raindrop, moving through the air, the and what is the most unsatisfactory part of the matter is that the theory affords do not know the cause. There is a heavy no clue to the reason why it should apply to the one class more than to the behave like a top.

other.

honor of lecturing in this room on the then novel subject of vortex motion, I ventured to insist that the reason why such ill success had attended our theoretical efforts was because, owing to the uniform clearness or opacity of water of water and air, we can see nothing of would hardly have been thought satisfacthe internal motion, and while exhibiting the phenomena of vortex rings in water, rendered strikingly apparent by partially coloring the water, but otherwise as strikingly invisible, I ventured to predict that the more general application of this method, which I may call the method of color bands, would reveal clues to those mysteries of fluid motion which had baffled philosophy.

To-night I venture to claim what is, at all events, a partial verification of that prediction. The fact that we can see as far into fluids as into solids naturally raises the question why the same success

It has long been a matter of very gen-should not have been obtained in the the most strenuous efforts of the ablest a rule there is no internal motion in solid mathematicians the theory of fluid mo-bodies, and hence our theory, based on reasons. The theory itself appears to be impossible that, at all events, a seemingly very tolerably complete, and affords the solid body should have internal motion. means of calculating the results to be and a simple experiment will show that expected in almost every case of fluid if a class of such bodies existed they motion, but while in many cases the the-would apparently have disobeyed the

These two wooden cubes are apparently just alike, each has a string tied to Now, if a ball is suspended by a string you all know that it hangs vertitheory gives us the true law of resistance; cally below the point of suspension, or but if we take a large body, such as a swings like a pendulum; you see this ship moving through the water, the theolone does so, the other, you see behaves retical law of resistance is altogether out; quite differently, turning up sideways. The effect is very striking so long as you revolving wheel inside, which makes it

Now, what I wish you to see is, that When, seven years ago, I had the had such bodies been a work of nature, so that we could not see what was going on-if, for instance, apples were of this nature while pears were what they are, the laws of motion would not have been discovered, or, if discovered for pears, would not have applied to apples, and so

Such is the case with fluids. are two vessels of water which appear exactly similar, even more so than the solids, because you can see right through them, and there is nothing unreasonable in supposing that the same laws of motion would apply to both vessels. The application of the method of color-bands. however, reveals a secret—the water of the one is at rest, while that in the other is in a high state of agitation.

I am speaking of the two manners of motion of water—not because there are only two motions possible; looked at by their general appearance the motions of water are infinite in number; but what it

^{*} Lecture at the Royal Institution, on Friday, March

is my object to make clear to-night is, that sinuous. In both cases there is a cerall the various phenomena of moving tain influence necessary for order: water may be divided into two broadly distinct classes, not according to what it is viscosity or treaclyness. with uniform fluids are their apparent motions, but according to what are the internal motions of the fluids which are invisible with clear fluids, but which become visible with color-bands.

The phenomena to be shown will, I hope, have some interest in themselves, but their intrinsic interest is as nothing compared to their philosophical interest. On this, however, I can but slightly touch. I have already pointed out that the problems of fluid motion may be divided into two classes, those in which the theoretical results agree with the experimental and those in which they are altogether different. Now what makes the recognition of the two manners of internal motion of fluids so important is, that all those problems to which the theory fits belong to the one class of internal motions. The point before us to-night is simple enough, and may be well expressed by analogy. Most of us have more or less familiarity with the motion of troops, and we can well understand that there exists a science of military tactics which treats of the best manœuvres to meet particular circumstances. Suppose this science proceeds on the assumption that the discipline of in the other it would inevitably lead to a the troops is perfect, and hence takes no scramble. The source of such a change account of such moral effects as may be in the manner of motion may be ascribed produced by the presence of an enemy, either to the delicacy of the manœuvre or Such a theory would stand in the same to the upsetting disarrangement, but as relation to the movements of troops as a matter of fact both these causes are that of hydrodynamics does to the move-necessary. In the case of extreme deliments of water. For although only discovery an infinitely small disturbance, such ciplined motion may be recognized in as is always to be counted upon, will military tactics, troops have another effect the change. Under these circummanner of motion when anything dis- stances we may well describe the conditurbs their order. And this is precisely tion of the troops in the simple manœuvre how it is with water; it will move in a as stable, while that in the difficult maperfectly direct disciplined manner under neuvre is unstable, i. e., will break down some circumstances, while under others on the smallest disarrangement. The it becomes a mass of eddies and cross small disarrangement is the immediate streams, which may be well likened to cause of the break-down in the same a whirling struggling mob, where each sense as the sound of a voice is sometimes individual element is obstructing the the cause of an avalanche, but since such others. Nor does the analogy end here. disarrangement is certain to occur a con-The circumstances whether the motion of troops shall be a the change. march or a scramble are closely analogous to those which determine whether of water. Supposing no disarrangement,

with troops it is discipline, with water better the discipline of the troops, or the more treacly the fluid, the less likely is steady motion to be disturbed under any circumstances. On the other hand speed and size are in both cases influences conducive to unsteadiness. The larger the army and the more rapid the evolutions, the greater the chance of disorder; so with fluid, the larger the channel and the greater the velocity the more chance of eddies. With troops some evolutions are much more difficult to effect with steadiness than others, and some evolutions which would be perfectly safe on parade would be sheer madness in the presence of an enemy. It is much the same with water.

One of my chief objects in introducing this analogy is to illustrate the fact that even while executing manœuvres in a steady manner there may be a fundamental difference in the condition of the fluid. This is easily realized in the case of troops, difficult and easy manœuvres may be executed in equally steady manners if all goes well, but the conditions of the moving troops are essentially different, for while in the one case, any slight disarrangement would be easily rectified, which determine dition of instability is the real cause of

All this is exactly true for the motion the motion of water shall be direct or the water would move in the manner indicated in theory, just as if there were no disturbance an egg would stand on its end, but as there is always some slight disturbance it is only when the condition of steady motion is more or less stable that it can exist. In addition then to the theories either of military tactics or of hydrodynamics, it is necessary to know under what circumstances the manœuvres of which they treat are stable or unstable. It is in definitely separating these that the method of color-bands has done good service, which will remove the discredit in which the theory of hydrodynamics has been held.

In the first place it has shown that the property of viscosity or treaclyness possessed more or less by all fluids is the general influence conducive to steadiness, while, on the other hand, space and velocity have the counter influence. Also that the effect of these influences is subject to a perfectly definite law, which is that a particular evolution becomes unstable for a definite value of the viscosity divided by the product of the velocity This law explains a vast and space. number of phenomena which have hitherto appeared paradoxical, one general conclusion is that with sufficiently slow motion all manners of motion are stable.

The effect of viscosity is well shown by introducing a band of colored water across a beaker filled with clear water at Then, when all is quite still, turn the beaker about its axis. The glass turns, but not the water, except that which is quite close to the glass. colored water which is close to the glass is drawn out into what looks like a long smear, but it is not a smear. It is simply a color-band extending from the point in which the color touched the glass in a spiral manner inwards; showing that the viscosity is slowly communicating the motion of the glass to the water within. To show this it is only necessary to turn the beaker back, and the smear closes up until the color-band assumes its radial position. Throughout this evolution the motion has been quite steady—quite according to the theory.

When water flows steadily, it flows in Water flowing along a pipe is such a stream.

faggot of indefinitely small streams, any one of which may be colored without altering its motion, just as one column of infantry may be distinguished from another by color.

If there is internal motion, it is clear that we cannot consider the whole stream bounded by the pipe as a faggot of elementary streams, as the water is continually crossing the pipe from one side to another, any more than we can distinguish the streaks of color in a human stream in the corridor of a theatre.

Solid walls are not necessary to form a The jets from a fountain or cascade in Niagara are streams bounded by free surfaces. A river is a stream half bounded by a solid surface. Streams may be parallel, as in a pipe; converging or diverging, as in conical pipes; or they may be straight and curved. All these circumstances have their influence on stability in the manner indicated in the accompanying diagram:

CIRCUMSTANCES CONDUCIVE TO

Direct or Steady Motion

(1) Viscosity or fluid friction which continually destroys disturb-Thus treacle is steadier than water.

(2) A free bounding surface.

(3) Converging solid boundaries.

(4) Curvature of the streams with the velocity greatest on the outSinuous or Unsteady Motion

- (5) Particular variation of velocity across the stream, as when a stream flows through still water.
- (6) Solid bounding walls.
- (7) Diverging solid bounding walls.
- (8) Curvature with the velocity greatest on the inside.

It has for a long time been noticed that a stream of fluid through fluid otherwise at rest is in an unstable condition. It is this instability which renders flames and jets sensitive to the slight disarrangement caused by sound.

I have here a glass vessel of clean water in front of the lantern, so that any color-bands will be projected on to the screen. You see the ends of two vertical tubes facing each other: nothing is flowing through these tubes, and the water in the vessel is at rest. I now open two taps, so as to allow a steady stream of colored water to enter at the lower pipe. This is bounded by the water flowing out at the upper. solid surface of the pipe, but if the water water enters quite steadily, forms a sort is flowing steadily we can imagine the of vortex ring at the end, which proceeds water to be divided by ideal tubes into a across the vessel, and passes out at the lower pipe. The colored stream then exerce, and even as seen by the method of tends straight across the vessel, and fills color-bands the reason for the sinuous both pipes: you see no motion; it looks motion is not obvious. If the current be like a red glass rod. The red water is, however, flowing slowly, so slowly that motion is the same in both parts of the viscosity is paramount, and hence the channel. Its changing in the expanding stream is steady. As the speed is increased, pipe seemed to imply that there the moa certain wriggling, sinuous motion appears in the column; a little faster and ought to appear from the theory. I am the column breaks up into beautiful and ashamed to think of the time spent in well-defined eddies, and spreads into the trying to make this out from the theory surrounding water, which, becoming without any result. I then had recourse opaque with color, gradually draws a veil to the method of color again, and over the experiment. The final breaking found that there is an intermediate up of the column was doubtless deter- stage. mined by some slight vibration in the apparatus, but such vibration, which is mediately ensuing motion is nearly the always going on, will not affect the stream until it is in a sufficiently unstable condi-The same is true of all streams bounded by standing water.

If the motion is sufficiently slow, according to the size of the stream and the viscosity, the stream is steady and stable. Then at a certain critical velocity, determined by the ratio of the viscosity of the water to the diameter of the stream, the stream becomes unstable. So that under any conditions which involve a stream through surrounding water, the motion becomes unstable at sufficiently great ve-

locities. Now one of the most noticeable facts in experimental hydrodynamics is the difference in the way in which water flows along contracting and expanding chan-Such channels are now projected on the screen, surrounded and filled with clean, still water. The mouth of the tube at which the water enters is wide; the tube then contracts for some way, then expands again gradually until it is as wide as at the mouth. At present nothing is to be seen of what is going on. On coloring one of the elemetary streams, however, outside the mouth, a color-band is formed. This color-band is drawn in with the surrounding water, and shows what is going on. It enters quite steadily, preserving its clear streak-like character until it has reached the neck, where convergence ceases; then on entering the expanding channel it is altogether broken up into eddies. Thus the motion is direct and steady in the contracting tube, sinuous in the expanding.

The theory of hydrodynamics affords no clue to the cause of this differ-

started suddenly at the first instant, the tion is unstable. If this were so, it

When the tap is first opened, the imsame in both parts; but, while that in the contracting tube maintains its character, that in the expanding changes its character: a vortex ring is formed which,

moving forwards, leaves the motion behind that of a parallel stream through the surrounding water. When the motion is sufficiently slow, the stream is stable, as already explained; there is then direct motion in both the contracting and expanding portions of the tube, but these are not similar, the first being a faggot of similar elementary contracting streams, the latter being that of one parallel stream through surrounding fluid. The first is a stable form, the second an unstable, and on increasing the velocity the first remains, while the second breaks down, and as before, the expanding tube is filled with eddies. This experiment is typical of a large class of motions. Whenever fluid flows through a narrow neck, as it approaches the neck it is steady, after passing the neck it is sinuous. The same is produced by an obstacle in the middle of a stream, and virtually the same by the motion of a solid through the water.

The object projected on the screen is not unlike a ship. Here the ship is fixed and the water flowing past it, but the effect would be the same were the ship moving through the water. In the front of the ship the stream is steady, so long as it contracts, until it has passed the middle; you then see the eddies formed as the streams expand again round the stern. It is these eddies which account for the difference between the actual and theoretical resistance of ships.

It appears then that the motion in the

expanding channel is sinuous, because and that found by Poiseuille, but also we the only steady motion is that of a stream through still water. Numerous cases in which the motion is sinuous may be explained in the same way, but not all. If is not yet completely ascertained, but we have a parallel channel, neither contracting or expanding, the steady moving streams will be a faggot of steady parallel elementary streams all in motion but having different velocities, those in the middle moving the fastest. Here we have a stream, but not through standing When this investigation began, it was not known whether such a stream was ever steady; but there was a wellknown anomaly in the resistance encountered in parallel channels. In rivers and all pipes of sensible size experience had shown that the resistance increased as the square of the velocity, whereas in very small pipes, such as represent the smaller veins in animals, Poiseuille had proved that the resistance increased as the velocity. Thus since the resistance would be as the square of the velocity with sinuous motion, and as the velocity in the case of direct motion, it appeared that the discrepancy would be accounted for if it could be shown sufficiently large velocities according to the size of the pipe. This has been done. You see on the screen a pipe with its end open. It is surrounded by water, and by opening a tap I can draw the water through it. This makes no difference to the appearance until I color one of the elementary streams, when you see a beautiful streak of color extend all along the pipe. So far the stream has been running steadily, and it appears quite stable. As the speed increases the color-band naturally becomes finer, but on reaching a certain speed the colorband becomes unsteady and mixes with the surrounding fluid filling the pipe. This sinuous motion comes on at a definso little, the band becomes straight and clear, increase it again and it breaks up. of the tube in the exact inverse ratio, the eddies below. smaller the tube the greater the velocity. er the velocity.

have complete evidence of the instability of steady streams flowing between solid The cause of this instability surfaces. this much is certain, that while lateral stiffness in the walls of the tube is unimportant, inextensibility or tangential rigidity is essential to the creation of eddies. I cannot show you this, because the only way in which we can produce the necessary condition is by wind blowing over the surface of water. When the wind blows over water it imparts motion to the surface of the water just as a moving solid surface. Moving in this way the water is not susceptible of eddies, it is unstable, but the result is waves. This is proved by a very old experiment, which has recently attracted considerable notice. If oil be put on the surface it spreads out into an indefinitely thin sheet, with only one of the characteristics of a solid surface, it offers resistance, very slight but still resistance to extension or contraction. This resisttance, slight as it is, is sufficient to entirely alter the character of the motion. It renders the motion of the water unthat the motion becomes unstable at stable internally, and instead of waves, what the wind does is to produce eddies beneath the surface. To those who have observed the phenomenon of oil preventing waves there is probably nothing more striking throughout the region of mechanics. A film of oil so thin that we have no means of illustrating its thickness, and which cannot be perceived except by its effects—which possesses no mechanical properties that can be made apparent to our senses—is yet able to prevent an action involving forces the strongest that we can conceive, able to upset our ships and destroy our coasts. This, however, becomes intelligible when we perceive that the action of the oil is not to calm the sea by sheer force, but ite velocity; diminish the velocity ever merely, as by its moral force, to alter the manner of motion produced by the action of the wind from that of the terrible This critical speed depends on the size waves on the surface into the harmless The wind brings the water into a highly unstable condition, Also the more viscous the fluid the great-linto what morally we should call a condition of great excitement; the oil, by an We have here, then, not only a com-influence we cannot perceive, directs this plete explanation of the difference in the excitement. This influence, although inlaws of resistance generally experienced, sensibly small, is, however, now proved seems that this instance of one of the most powerful mechanical actions of which the forces of nature are capable of being entirely controlled by a mechanical force, so slight as to be imperceptible, does away with every argument against strictly mechanical sources for what we may call mental and moral forces.

But to return to the instability in parallel channels. This has been the most complete, as well as the most definite result of the method of color-bands. circumstances are such as render definite experiments possible; these have been made, and reveal a definite law of instability, which law has been tested by reference to all the numerous and important experiments that have been recorded with reference to the law of resistance in pipes, whence it appears that the change in the variation of the resistance from the velocity to the square of the velocity agrees as regards the velocity at which it occurs with the change from stability to instability. It is thus shown that water behaves in exactly the same manner, whether the channel is, as in Poiseulle's experiments, of the size of a hair, or whether it be the size of a water main or of the Mississippi, the only difference being that, in order that the motions may be compared, the velocities must be inversely as the size of the channels. This is not the only point explained.

If we consider other fluids than water, some fluids like oil or treacle apparently flow more slowly and steadily than water; this, however, is only in smaller channels. The velocity at which sinuous motion commences increases with the viscosity. Thus, while water in ordinary streams is always above its critical velocity and the motion sinuous, the motion of treacle in such streams as we see is below its critical velocity and the motion is steady. But if nature had produced rivers of treacle the size of the Thames, the treacle would have flowed as easily as water. Thus, in the lava streams from a volcano, although looked at closely the lava has the consistency of a pudding, in the large and rapid streams down the mountain side the lava flows with eddies like water.

This relates to the effect of curvature in above this the influence of the tempera-

to be of a mechanical kind, and to me it the streams on the stability of the motion. Here again we see the whole effect altered by apparently a very slight cause. If the water be flowing in a bent channel in steady streams, the question as to whether the motion will be stable or not turns on the variation of the velocity across the channel. In front of the lantern is a cylinder with glass ends, so that the light passes through in the direction of the axis. The cylinder is full of water, the disk of light on the screen being the light which passes through this water, and is bounded by the circular walls of the cylinder. By means of two tubes temporarily attached, a stream of color is introduced so as to form a color-band right across the cylinder, extending from wall to wall; the motion is very slow, and, the taps being closed and the tubes removed, the color-band is practically stationary. The vessel is now caused to revolve about its axis. At first only the walls of the cylinder move, but the colorband shows that the water gradually takes up the motion, the streak being wound off at the ends into two spiral lines, but otherwise remaining still and vertical: when the streak is all wound off and the spirals meet in the middle, the whole water is in motion. But as the vessel is still revolving, the motion is greatest at the outside, and is thus stable. There are no eddies, although the spiral rings are so close as nearly to touch each other. The vessel stops, and gradually stops the water, beginning at the outside. If this went on steadily, the spirals would be unwound and the streak restored; but as the velocity is now greater towards the center, the motion is unstable for some distance from the outside, and eddies form, breaking up the spirals for a certain distance towards the middle, but leaving the middle revolving steadily. Besides indicating the effect of curvature, this experiment neatly illustrates the action of the earth's surface on the air moving over it, the variation of temperature having much the same effect on the stability of the moving fluid as the curvature of the vessel. The moving air is unstable for a few thousand feet above the earth's surface, and the motion consequently sinuous to this height. mixing of the lower and upper strata There is now only one experiment left. produces the heavy cumulus clouds, but

tare predominates; the motion is stable, and clouds, if they form, are stratus, like the inner spirals of the color bands.

REPORTS OF ENGINEERING SOCIETIES.

MERICAN SOCIETY OF CIVIL ENGINEERS, May 21, 1884. Vice-President Wm. H.

Pane in the chair, John Bogart, Secretary.

A description of a permanent transmitting dynamometer, constructed by the late Prof. Charles A. Smith, M. Am. Soc. C. E., was read. This dynamometer was put up in connection with the machine and engine rooms of the Manual Training School at St. Louis, and has been in coustant use for seven years. Its peculiarity is simplicity. The tension of a belt being measured through a balance beam which compresses a spring.

The subject of temperature of water at various depths was discussed by Mr. D. J. Whittemore, President of the Society, who referred to the fact that cold water is frequently obtained by mariners upon the Great Lakes by sinking a corked jug to some depth, and then by withdrawing the cork the jug is filled with water

very cold and refreshing.

Observations upon the temperature of the water at various depths in Pine Lake, Wiscon-

sin, were also represented.

Temperature observations upon Lake Superior, show comparatively constant temperature at the bottom, of about 39 degrees, and in depth from 400 to 100 feet.

Observations upon the temperatures of the earth, as shown by deep mines, were presented by Messrs. Hamilton Smith, Jr., and Edward B. Dorsey. Mr. Smith said that the temperature of the earth varies very greatly at different localities and in different geological formations. There are decided exceptions to the general law that the temperature increased with the depth. At the New Almaden quicksilvermine in California, at the depth of about 600 feet the temperature was very high—some 115 degrees, but in the deepest part of the same mine, 1,800 feet below the surface and 500 feet below sea level, the temperature is very pleasant, probably less than 80 degrees.

At the Eureka mines in California the air, 1,200 feet below the surface, appears nearly as cool as 100 feet below the surface. The normal temperature of the earth at a depth of 50 or 60 feet is probably near the mean annual temperature of the air at the particular place. At the Comstock mines, some years since, the miners could remain but a few moments at a time on account of the heat. Some ice water was given them as an experiment; it produced no ill effects, but the men worked to much better advantage, and since that time ice-water is furnished in all these mines and drunk with appar-

ently no bad result.

Mr. E. B. Dorsey said that the mines on the Comstock vein, Nevada, were exceptionally hot. At depths of 1,500 to 2,000 feet, the thermometer placed in a fresh drilled hole will show 130 degrees.

Very large bodies of water have run for years

at 155 degrees and smaller bodies at 170 de-

The temperature of the air is kept down to 110 degrees by forcing in fresh air cooled over

Captain Wheeler, U. S. Engineer, estimated the heat extracted annually from the Comstock by means of the water pumped out and cold air forced in, as equal to that generated by the combustion of 55,560 lons of anthracite coal, or 97,700 cords of wood. Observations were then given upon temperature at every 100 feet in the Forman shaft of the Overman mine, running from 53 degrees at a depth of 100 feet to 121-2 degrees at a depth of 2,300 feet. The temperature increased:

100 to 1,000 feet deep, increase 1° in 29 feet. 100 to 1,800 " " 100 to 2,300 " " " 1° in 30-5 "
" 1° in 32.3 "

A table was presented giving the temperatures of a large number of deep mines, tunnels and artesian wells. The two coolest mines or tunnels are in limestone, namely, Chanarcillo mines and Mt. Cenis tunnel, and the two hottest are in trachyte, and the "coal measures," viz., the Comstock mines in trachyte and the South Balgray in the "coal measures." Mr. Dorsey considered that experience showed that limestone was the coolest formation.

Mr. Theodore Cooper gave a description of a curious slide or slump which recently occurred near Dover, New Hampshire, a large section of a clay formation having gone bodily into the adjacent river, moving trees with it but leaving between the river and the cavity a bank of con-

siderable width.

June 4th, 1884.—Vice-President Wm. H. Paine in the Chair, John Bogart, Secretary.

Ballots were canvassed and the following candidates were elicted:-

As Members:—James P. Allen (transferred from Junior), Charleston, S. C.; Henry P. Bell, Winnipeg, Manitoba; William F. Biddle, Philadelphia, Pa.; Wendell R. Curtis (transferred from Junior). Savannah, Ga.; Chauncey Ives, Chambersburg, Pa.; Mace Moulton, Wilmington, Del.; Samuel Rae, Philadelphia, Pa.: Percival Roberts, Jr. (transferred from Associates), Philadelphia, Pa.; Levi L. Wheeler, St. Louis, Mo.

As Associates:—Alan, H. G. Hardwicke, Buffalo, N. Y.; William Roberts, Waltham, Mass.

Juniors:-William H. Buckhaupt, St. Louis, Mo.; Allan D. Conover, Madison, Wis.: Martin Gay, West New Brighton, N. Y.; Silas B. Russell, St. Louis, Mo.; Chandler D. Starr. New York City.

A paper was read by A. M. Wellington, M. Am. Soc. C. E., giving the details and results of experiments with a new apparatus upon the friction of car journals at low velocities. These experiments were undertaken to test the correctness of a series of tests described in a previous paper, which was made by starting cars from a state os rest down a known grade, and deducing the resistance from the velocity acquired. The present experiments were made by an apparatus in which the axle to be tested is placed in an ordinary lathe having a great variety of speeds, the resistance of the axle being measured by the levers connected with a voke encircling the axle, and transmitting the pressures to a suitable weighing apparatus. It was found important that this weighing apparatns should be direct, as for instance, a platform scale rather than a spring scale. The results of these experiments, as to initial friction, were that friction at very low journal speed is abnormally great, and more nearly constant than

any other element of friction.

This abnormal increase of friction is due solely to the velocity of revolution. At velocities slightly greater, but still very low, the fric-tion is still large, the co-efficient falling very slowly and regularly as the velocity is increased, but being constantly more and more affected by differences of lubrication, load and temperature. A very slight excess of initial friction would generally be observed. There is no such thing as a journal friction, as a friction of rest in distinction from a friction of motion. The fact that friction of rest appears to exist is due solely to the fact that no journal or other solid body can be instantly set into rapid motion by any force however great. At ordinary operating velocities the character and completeness of Inbrication seems to be much more important than the kind of oil used, or even the

pressure or temperature.

Comparisons were made of experiments by Prof. Thurston and by Mr. Tower, and the experiments of the anthor. The rolling friction proper in railroad service seems to be very small indeed, not exceeding one pound per ton. As to the resistance of freight trains in starting, it is believed that the resistance at the beginning of motion, in each journal, is about eighty pounds per ton. A velocity of from one-half to three miles an hour must be obtained before the journal friction falls to ten pounds per ton. At six miles per hour the journal friction is at least one pound per ton higher than at usual work-ing speeds. Temperature exerts a very marked adverse influence upon friction at low velocities. The velocity of lowest journal friction is 10 to 15 miles per hour. With bath or other very perfect lubrication there is a very slight increase of journal friction accompanying velocities up to 55 miles per hour. With perfect lubrication, as with pad or siphon, greater velocity is as apt to decrease as to increase the co-efficient. The latter being more like the ordinary lubrication in railroad service, we may say without sensible error that the co-efficient of journal friction is approximately constant for velocities of 15 to 50 miles per hour.

The paper was discussed by members present.

INGINEERS' CLUB OF PHILADELPHIA—SPECIAL BUSINESS MEETING, MAY 17th, 1884. Vice-President J. J. deKinder in the chair, the Secretary presented, for Mr. Edward Parrish, an illnstrated account of the Effect of Sea Water on the Iron Brandywine Shoal Lighthouse. This Lighthouse was built in 1849-50, near the mouth of the Delaware Bay, and stands in about six feet of water. It is the first screw-pile structure built in the United States, and has but few predecessors in the world. The house is sup-

rounded by fifty-two piles of rolled iron, acting as an ice fender. The whole is strengthened by systems of braces and ties. The effect of the water on the iron, continually submerged, has been to produce longitudinal seams or grooves, with occasional holes on the surface; in some cases seriously reducing the strength. most extensive corrosion is observed on the hammered iron. Round rods in the air are altered in section approximating an irregular polygon with longitudinal grooves.

The Secretary presented, for Mr. Sam'l Rea, "A Treatise on Bridge Architecture in which the Superior Advantages of the Flying Pendent Lever Bridge are Fully Proved," by Thomas Pope, New York, 1811, with Mr. Rea's com-

ments thereuponr.

Prof. L. M. Hanpt read an illustrated paper on Rapid Transit, giving valuable data relative to the effects of velocity of movement on the ratio of increase of population, and contrasting the situation in New York and Philadelphia. In comparing the topography of the two cities, a silhontte of Manhattan Island was laid on a map of Philadelphia (same scale), showing that the island, from the battery to 150th Street, (nine and a half miles), only extended from Leagne Island to Eric Ave. From this it was inferred that, if there was need for elevated roads in New York, there was greater need for them in Philadelphia "as the necessity is proportional to the extent of snrface of a city and the distance of its residents from the business centers." The former commercial supremacy of Philadelphia was considered, with the reasons for the rapid decline in the ratio of increase of population, which has diminished from 79 per cent. in the decade 1840-50 to 25 per cent. for 1870-80, whilst Camden's population has increased from 51 per cent. in 1850-60 to 108 per cent. in 1870-80. In short, Philadelphia is overflowing because her time limits of travel are too restricted. Assuming the time limit at thirty minutes each way or one honr per day, at the usual velocities of travel, the limits of the

"Pedestrian City" were found to be a square with diagonals of 4 miles and area 8 square

"Horse Car or Cable City," were found to be a square with diagonals of 6 miles and area 18 square miles.

"Elevated R. R. City," were found to be a square with diagonals of 12 miles and area 72

square miles.

"Underground City," were found to be a square with diagonals of 20 miles and area 200

square miles.

The total area of Philadelphia is 129 square miles, and of the built-np portion $13\frac{1}{2}$, or $10\frac{1}{2}$ per cent. Deducting from the square representing the "strect car city," the salient intercepted by the Delaware River, it leaves just the same area, or $13\frac{1}{2}$ square miles, showing the city to have reached the limit of street car travel. The areas benefited vary as the squares of the velocity of travel; hence elevated roads would be worth to the city four times as much as surface lines, and underground roads about eleven times as mnch. Since 1850 Philadelphia has lost in population one-half a million people ported on nine piles of hammered iron, sur- equivalent to a revenue on the real estate which

they would have occupied and improved of about \$2,000,000 per annum. The two broad zones of the overcrowded portion of the city were also outlined, and the extent of the bencfits to be conferred by only two lines of elevated roads were clearly shown by diagrams to extend to the entire city, Elevated roads occupy an intermediate position in cost of construction, rate of travel and general utility between surface and underground structures, and there can be no doubt that the time has fully arrived when this city, for her own sake, requires them and should heartily co-operate with any parties so proposing to improve and extend her resources. The following were some of the conclusions arrived at.

1. The city has reached and already surpassed

the ordinary limits of street car travel.

2. The ratio of increase of population is rapidly declining chiefly from lack of more

rapid and cheaper means of transit.

3. The present steam roads in the city cannot supply the demand as they are surface line trains and must move slowly and cannot be run at close intervals; farcs are too high and stations too distant.

4. Camden, N. J., is rapidly gaining popu-

lation at the expense of Philadelphia.

5. The annual loss to the city in revenue from the cause will reach millions of dollars

6. Unless relief is afforded the city will be corralled by time limits and the density of the population must increase rapidly at the expense of health and morality.

7. Two lines of elevated railroads at right angles to each other, and properly located, would benefit an area equal to double that of

the built up portion of the city.

8. The fears of opponents of elevated of roads of losses to the city or the individual, from withdrawal of patronage or depreciation of property, arc shown by experience in New York to be groundless.

9. If Philadelphia desires to retain even the present low rate of increase in population, and high rate of salubrity, she must promptly respond favorably to the request of her citizens

to be permitted to build elevated roads.

10. The limits of the city are not such as to warrant any corporation in building an underground road were it recommended or allowed, with any fair prospects of returns, for many

years.

Mr. Wm. H. Ridgway read a paper upon the Action of Water in the Modern Turbine, claiming that it is nothing more than an improved Barker's Mill, and that there is no such thing as the water spurting through the shutes and impinging on the buckets as is generally believed, —the wheel on the contrary taking a velocity very much greater than that of the inflowing water.

Mr. J. J. deKinder presented an illustrated description of a method of Removing Condemned Machinery by Dynamite, as practiced by him in the case of the side levers of the old Cornish Pumping Engine at Spring Garden Water Works, Philadelphia, which weighed 29,000 lbs. each. Drilling, tapping and break-ing each beam in two, with half a pound of dynamite, and without injury to the building position and character of many of the present

or other machinery, occupied thirteen hours. Even had dispatch been unnecessary, it might have taken two weeks to do this work by the

ordinary methods.

The Tellers of Election reported that one hundred votes had been cast, and the following gentlemen elected Active Members of the Club.

John H. Converse, W. Henry Sayen, I. Norris DeHaven, Alter Megear, Benj. P. Howell, T. A. M. Matsdaira, R. W. Davenport, John N. Pott, J. B. Wilson, Walter C. Brooke, W. Brooks Cabot, Gaylor Thompson, Wm. B. Henszey and Archibald Stevenson.

REGULAR MEETING, JUNE 7th, 1884.

President Wm. Ludlow in the chair, 27 mem-

bers and 3 visitors present.

The president announced, in relation to the question of new and enlarged quarters for the Club, that a house could be obtained in the fall. in Girard Street, and requested the members to be prepared to discuss and act upon the subject at the next meeting.

Mr. Wm. H. Ridgway described a simple crane, consisting of a cylinder hung from the jibs of an ordinary foundry crane, and using the steam directly to hoist the load; and also an elevator, in which water, receiving pressurefrom the direct application of steam acting upon a piston carrying a rack, gave motion to a shaft

carrying a pinion and drum wheel.

Mr. C. Henry Roney exhibited specimens of American Sectional Electric Underground Conduits as laid in Philadelphia, described method of their construction in detail, the difficulties encountered in avoiding the present underground works, the manner of introducing and arranging the wires, and the behavior of the electric currents therein.

Prof. L. M. Haupt supplemented his paper of May 17th, upon Rapid Transit, by an interesting collection of statistics of the growth of the city from the time of the "pack horse" to the present, and showed, by maps, that his pre-vious statements were verified by these sta-

tistics.

Mr. A. E. Lehman exhibited to the club a model of a new protractor, and described the invention and the improvements he has made in it. It consists of a combination of pro-tractor, T square, scales, etc., which may be worked separately or together. As a protractor only, it is complete, being graduated to degrees and fractions thereof and provided with a vernier reading to three minutes. It can be used, like an ordinary paper of ivory pro-tractor, for hasty plotting, and combines triangles and scales in one instrument. For careful and precise work it is said to be equal to the best special instrument and to be no higher in

Mr. E. V. d'Invilliers read a paper on "Some Characteristics and the Mode of Occurrence of the Brown Hematite (Limonite) Ores in Central Penna," taking for his field of illustra-tion the lower Silurian limestone valleys of Centre Co. He described the anticlinal structure of these valleys, and the great erosion, arial and sub-arial, which these rocks (6,000

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ore deposits. He applied this principle to the different ferriferous limestone beds, and explained how this effect was aided by the alternate rise and fall of the anticlinals along the trend of their axes. He noted three varieties of ore: 1st. The wash and lump hematite of the Barrens. 2d. The true limestone "pipe ore." 3d. An intermediate transition variety. The first is always associated with the sandy magnesian beds low down in the series of No. II., or below 5,000 feet beneath the overlying Hudson River Slates of No.III. This class shows rounded ore and flint balls and tough, barren clay, and are secondary or derived deposits of irregular shape. They have been tested 100 feet deep, and contain from 45 to 53 per cent. iron, and .051 to .113 phosphorus. The almost total absence of bisulphide of iron is noticeable. Cost of mining about \$1.50 per ton. The transition variety was assigned a position in the formation from 3,500 to 5,000 feet below the slates. They are characterized by a more calcareous clay, are compact, amorphous, liver colored ores, containing from 40 to 49 per cent. iron and from .115 to .365 per cent. phosphorus. The pipe ores occur usually higher in the limestones than either of the other two. but in this country below the 400 feet of upper Trenton layers. These ores occur in situ, between parallel walls of limestone; in plate-like masses, scales, or as cylindrical pipes in bunches 8 or 10 feet long, while feathering out both in line of strike and dip. The deeper banks show the repeated occurrence of crystals of iron pyrites in all stages of metamorphism. They occur at great depths, and show from 45 to 53 per cent. iron and from .100 to .185 per cent. phosphorus. The flint or quartz grains accompanying them are rarely water worn, and this clay is very calcareous and easily washed, not requiring the jigging necessary for cleansing the lower ores. Cost of mining these ores varies from 90 cents to \$1.25 per ton.

Prof. L. M. Haupt called the attention of the club to a bill, pending in Congress, to consolidate the U.S. Coast and Geodetic Survey with

the Navy Department.

Captain S. C. McCorkle, of the Coast Survey, who was present, explained the effect that its passage would have upon the future of the work, and President Wm Ludlow gave, from his own experience and knowledge, the reasons why this change was contemplated. The Section 1985 of the contemplated of the section was contemplated. retary read his correspondence with Hon. Sam'l. J. Randall upon the subject, and expressed what he believes to be the unanimous sentiment of the Civil Engineering profession of the country, against any interference with a Survey, the perfection of whose results is proverbial, and against any increase of the already unwise and unjust discrimination of the Government against thoroughly competent Civil Engineers, and in favor of a class who often (but with notable exceptions) have, comparatively, but little ability, and whose only claim is that the Government has attempted to educate them, and must, therefore, seem to provide them with something to do.

IOHIGAN ASSOCIATION OF SURVEYORS AND CIVIL ENGINEERS.—Contents of Proceedings: Third meeting.

I. History of Legislation for Surveyors. II. Foundations and Piers of the Wheeling

& Lake Erie Railroad Bridge, at Toledo, Ohio. By Prof. Chas. E. Green.

III. Water Works for Small Cities. By G.W.

Pearsons, Kansas City, Mo.
IV. Reform School for Girls. By Burton Kent, Adrian.

V. Compass Deviations on Vessels and the Conversion of Compass Courses. By H. C. Pearsons.

VI. Drainage Engineering. By R. C. Carpenter.

VII. Practical Questions. By J. H. Leavenworth.

VIII, Horizontal and Vertical Distances Without the Use of a Vertical Arc or Stadia Wircs. By H. C. Pearsons.

Contents of Proceedings: Fourth Meeting.

Legislative Needs of Surveyors. By George

E. Steele.
The North Lansing Mill Dam. By A. D. Bartholemew.

Wooden Pavements. By H. G. Rothwell. Water as a Source of Engineering Difficulty. By Prof. Chas. E. Green.

Common Roads. By Burton Kent,

By A. J. Difficulties in City Surveying.

Logging Railroads. By E. F. Guild. Practical Questions. By J. H. Leavenworth. Necessary Instruments for Surveyors. Prof. J. B. Davis.

Surveying for Railroads. By F. Hodgman. Projection of a Parallel of Latitude. . By H. Pearsons.

Traverse Surveying. By Prof. J. B. Davis. Engineering of Town and County Drains. By S. N. Beden. A Level Line of Sight. By Prof. J. B.

Davis.

The Judicial Functions of Surveyors. By Justice Cooley.

ENGINEERING NOTES.

BOARD OF TRADE report has been published on the works in progress for the construction of the bridge over the river Forth, from which it appears that the most important works at South Queensferry consist of the coffer dams for the south cantilever pier and for No. 7 viaduct pier. The former is composed of two rows of 12in. sheet piling, with outside struts bearing against the piles, and sustained inter-nally by heavy cross timbers. The dam meas-ures 115 ft. by 65 ft. inside, and the piles, which average 47 ft. long, are driven about 21 ft. into the ground. With a view to safety and expedition the dam has been divided into two halves; the eastern half is completed, the water pumped out, and a trial pit sunk in the center to ascertain the depth of the hard clay; at a depth of 9 ft. below the surface, and 12 ft. below low water of spring tides, a compact layer of boulders, averaging 18 in. thick, was reached, and immediately below this the hard boulder clay was entered, which appears to be very stiff and compact. The piles of the western half of the dam are nearly all driven, and it is expected

that the water will shortly be pumped out and the excavation commenced. About 96,000 cubic feet of granitc have been delivered, of which 64,000 cubic feet have been sct, and about 8,000 cubic yards of concrete are now in position.

A FTER full consideration of about twenty plans of sewerage and sewage disposal, submitted by different engineers, for the district of Southall and Norwood-Middlesex-the Uxbridge Rural Sanitary Authority, has decided on that prepared by Mr. John Anstic, C.E., of Westminster-Chambers, and proposes, subject to the approval of the Local Government Board, to commence the works as soon as arrangements can be made for purchase of the lands required for the disposal of the sewage, which belongs to the Earl of Jersey. The scheme provides for the main sewerage of a district about four square miles in area, with a view to a considerable portion of it being hereafter built upon, the disposal of the sewage being effected by means of precipitating tanks, and subsequent natural filtering of the water through an area of land specially prepared. The undertaking is estimated to cost about £10,000.

TRIAL was recently made at Messrs. Grant, A Ritchie & Co.'s works, Kilmarnock, of one of Mr. Joseph Moore's patent hydraulic In these pumps there are no pump rods, and in their place there are two pipes of small diameter, in which is contained water under a pressure of 1,000 lbs. per square inch. This water serves as a hydraulic rod for transmitting the power from the engine on the surface to the pumps underground, and enables the pumps to be placed round any number of turns and at any distance from the engine. The pump which Messrs. Grant, Ritchie & Co. tested is for the Broxburn Oil Company. engine will be placed on the surface and the pump down a drift 300 yards long. The vertical lift will be 720 ft. In the trials the pnmp was placed 120 ft. from the engine, and water was discharged at a pressure of 200 lbs. per square inch. It worked throughout very smoothly and efficiently. The system is also suitable for sinking, in which case the columns of pipes and the plungers slide in wooden guides in the same manner as a cage. They are suspended by two sets of rods from a hydraulic ram, which raises and lowers the pumps and pipes in the sinking process.

IRON AND STEEL NOTES.

Here W. Hupfeld, an engineer of Prevali, Austria, recently published the results of a series of experiments on welding steel in the Oestreichische Zeitschrift fur Berg-und Hutten-Wesen. He instances the fact that the Austrian navy, in its specifications for steel angles, has a welding test which will certainly be conceded to be severe. One of the sides is cut, the angle is bent at right-angles, the flaps are welded together, and, when cold, the angle is again bent straight. This test the Austrian Bessemer steel will stand, the material having from 0.20 to 0.25 carbon, and a tensile strength of from 40 to 50 kilogs. During twenty-seven blows,

Herr Hupfeld cast two sample ingots 70 mm. square and 300 mm. long, onc of which was used for the welding test, and the other for the corresponding test of metal not welded. One ingot was cut in two, and a butt well made, each end being tapered so that, put together, they had a bearing surface of 70 mm. Then, after a second low heat, the welded part was forged under a steam hammer to 20 mm. square, and the rod turned to a diameter of about 15 mm., and well polished. When tested the bars yielded results which showed hardly any deterioration through welding. Phosphorus, the Engineering and Mining Journal mentions, was in no case above 0.045, and sulphur not over 0.02 per cent. The tests show that by welding the tensile strength is, on an average, diminished by only 1.75 per cent., the maximum being 5 per cent., and that the ductility is increased by exactly the same amount.

PROTECTING STEEL AND IRON FROM RUST.-Professor Calvert has recently made the interesting discovery by practical tests, that the carbonates of potash and soda possess the same property of protecting iron and steel from rust as do those alkalies in a caustic state. Thus it is found, that, if an iron blade immersed in a solution of either of the above carbonates, it exercises so protective an action, that that portion of the iron which is exposed to the influence of the damp atmospheric air does not oxidize, even after so extended a period as two years. Similar results, it appears, have also been obtained with sea-water, on adding to the same the carbonates of potash or soda in suitable proportion.

FINE FINISH FOR STEEL.—A Fine lusterless surface on tempered steel can be procured by either of the following operations: After the steel article has been tempered, it should be rubbed on a smooth iron surface with some pulverized oil-stone, until it is perfectly smooth and even, then laid upon a sheet of white paper, and rubbed back and forth until it acquires a fine dead finish. Any screw-holes, or depression in the steel, must be cleaned be-forehand with a piece of wood and oil-stone. This delicate, lusterless surface is quite sensitive, and should be rinsed with pure soft water only. A more durable finish is obtained by smoking the steel surface with an iron polisher and some powdered oil-stone, carefully washing and rinsing; then mix in a small vessel some fresh oil and powdered oil-stone; dip into this mixture the end of a piece of elder-pitch, and finish the steel surface with a gentle pressure, cutting off the end of the pitch as it commences to become soiled. In conclusion, it should be thoroughly cleaned in soft water, when the article will be found to have a fine lusterless finish.—Popular Science Series.

RAILWAY NOTES.

"Instructions with reference to Sanders-Bolitho automatic vacuum brake" on the Midland Railway have been issued, which show that it is not an automatic brake. One paragraph says:—"In the event of a train becoming divided when going up a rising gradient, the

guard must, in addition to turning the tap to the 'remaiu-on' position, also apply his hand brake tightly, and take such other measures as may be necessary to prevent the vehicles from moving.

The gauge iu India controversy is opening up a burning topic, and the battle of the gauges will have to be fought again. There are no less than five railway gauges in India—the 5 ft. 6 in., or broad gauge, the 3 ft. 3 in., or meter gauge, the 4 ft. used on the Azimganj Railway, the 2 ft. 6 in. gauge of the Gaekwar of Baroda's line, and the 2 ft., or military gauge of the Himalayan Railway. Practically the contest now lies between the broad and meter gauges; the most important lines have been laid on the former, and the broad gauge is the proper one to survive. What is now desired is uniformity, as the present breaks of gauge, and consequent shifting of goods add considerably to the cost of transport, though Indian railways now pay.

In a report on an accident, which occurred on the 28th February, at Fenchurch street on the 28th February, at Fenchurch street station on the great Eastern Railway, when, as a passenger train was entering Fenchurch street station, the engine left the rails with all its wheels at the sharp curve leading from the right-hand up line to No. 5 platform line, and was stopped after running about 49 yards, Major-General Hutchinson says:—"The train consisted of an eight-wheeled tank engine, with a four-wheeled trailing bogie, and a train of twelve vehicles, fitted throughout with the Westinghouse brake. This accident, which is almost a repetition of those which occurred at the same spot last October, must, I think, be attributed to the speed having been too high round the sharp curve of five chains radius, and to the gauge at the points being unnecessarily tight, the result being that the left leading wheel of the engine left the rails at the outside of the curve, having crossed the left switch 15 in. from its tip."

W HILE Germany has 21,865, England 18,-685, and France 18,050 miles of railway, Turkey has only 1,015 miles, though her population is almost as numerous as that of these three countries. There are four lines of railway now open for traffic, the most important being the Roumelian lines, which are 730 miles long; and upon which, in 1881—the last year for which statistics have been given—the receipts were £587 a mile. The Smyrna, Cassaba and Alachur Company has 295 miles of railway, which in 1881 carried 395,000 passengers and 470 tons of goods; its receipts being £1,125 to the mile. The Aidin Company has 120 miles of railway, and carried 190,000 passengers and 500,000 tons of goods; its receipts being £1,088 to the mile. The Haidar Pasha line is 58 miles long, and its receipts in 1881 were £573 per mile. There is also a short line, 26 miles long, from Mondavia to Broussa, which was opened a few years ago. But it has been allowed to fall into disuse, and the inhabitauts of the district through which it passes are using the German, and subsequently at Southampton by sleepers as firewood, and the rails themselves the British Government.—*Engineer*.

to brace up their houses. Four new lines are now in course of construction.—Engineer.

ORDNANCE AND NAVAL.

YASTING CANNON FOR THE AMERICAN GOVERN-MENT. - A 12-inch rifle mortar, intended as an experimental gun, was cast recently, by the South Boston Ironworks. This is the beginning of renewed activity in gun-making after a period of seven years, during which this portion of the plant has lain idle. This is the first of five heavy experimental guns contracted for by the Ordnance Department last September. The other guns will be cast shortly. One will be a 10-inch breech-loading rifle, the body to be of cast iron, which is to be reinforced by a wrapping of steel wire. Another will be a 12-iuch breech-loading rifle entirely of cast iron, and is to weigh, when finished, some 57 tons. The fourth is to be like the last in all respects, with one exception, that it is to be lined from the breech with a short steel tube, to reach a little beyond the trunnions. The fifth is to be a 12-inch breech-loading rifle, the body to be of cast iron, but to be reinforced by steel rings around the breech, and to be lined the full length with a steel tube. The material used in all the castings will be the Salisbury charcoal iron, mined and smelted in Western Massachusetts. The guns are cast on the rodman system. The South Boston Ironworks have also contracted with the Navy Department for the breech-loading rifles to armor the new cruisers which Johu Roach is now building.

THE Chinese war steamer, Nan Thin, which was lately detained at Newcastle-on-Tyne, by order of the British Government, was built by Mr. George Howaldt, of Kiel, aud was launched in the latter part of last year. The vessel was not built for the Imperial Government, but for the Viceroy of Canton, who possesses a small navy of his own. She is a steelbuilt corvette of 2,200 tous, and is barque rigged. Her principal dimensions are: Length between perpendiculars, 277 ft.; breadth, extreme, 38ft.; depth in hold, 23ft. 4in.; draught of water, 18ft. She is propelled by twin screw eugines of 3,000 indicated horse-power, manufactured by her builder, and she is said to steam at the rate of 14½ knots per hour. Her armament consists of two 9in. and eight 40pounder breech-loading Armstrong guns, and it was for the purpose of taking these on board that she proceeded to Newcastle. The action of the British Government in embargoing this vessel has created much surprise on the Continent; as no valid excuse can be found for her deteution. It is maintained by competent authorities that-the German Government only is responsible for any breach of international law which may have been caused by her departure from a German port. It will be remembered that Mr. Howaldt was the builder of the ci devant Peruvian cruisers, Diogeues and Soc-

THE NEW SCREW GUN VESSEL FOR THE NAVY. —On the 7th May H. M. S. Reindeer, screw gun vessel, which was built at Devonport and launched in November last, was taken into the Channel for a peliminary trial of her machinery, which has been fitted by Messrs. R. and W. Hawthorn, St. Peter's Works, Newcastle. The Reindeer is one of five vessels of a class which is an improvement on the Dolphin and Wanderer, recently commissioned at Shecrness. Four of the ships, including the one tried, have been or are being constructed, at Devonport, those on the stocks at present being the Mariner, Racer, and Icarus. The fifth, the Acorn, is being built at Pembrokc Dock. The Reindeer is fitted with six 5in. guns, two on either slde, one forward, and the other aft. When the start was made the weather was very threatening, and before the ship had been long outside the wind rose to a galc. Nevertheless the trial proceeded very smoothly, the machinery working splendidly throughout. The engines are horizontal, compound, surface condensing, with high cylinder 32in. and low 54in. in diameter. with 3ft. stroke. The engines are fitted with Mr. F. C. Marshall's patent valve gear, having one eccentric only for each cylinder, which reduces the number of working parts to a minimum. The engines arc so arranged as to cut off steam between 17 per cent. and 60 per cent. of stroke without expansion valve. ship is fitted with three boilers 7ft. 2in. diameter by 16ft. 9in. long. When the trial commenced the steam in the boilers was 90 lb., the vacuum in the condensers 26,25in., the mean revolutions per minute 74, mean pressure in the higher 9.8 lb., in the low cylinder 12.4 lb. For one hour the engines were woeked as the highest grade of expansion, giving 106 horse-power in the high-pressure, cylinder and 384 in the low-pressure cylinder—total 490. The engines were then worked at different grades of expansion with satisfactory results. The machinery was then gradually worked up to full power, the steam in the boilers being 82 lb.; the vacuum in the condensers, 26in.; revolutions 96 per minutc; mean pressure in the high cylinder, 23 lb.; in the low cylinder, 14.3 lb.; giving an indicated horse-power, high, 322; low, 572—total 894. The engines were next tried at one hour jet injection. The mean steam in the boilers was 75 lb., the vacuum in the condensers, 19in.; revolutions, 75.8 per minute; mean pressure in the high cylinder, 17.4 lb., in the low cylinder, 11.4 lb.; horse-power, high, 193; low, 361—total, 554. Stopping and starting were next tried. The engines going full speed ahead were stopped in three seconds; being stopped, they were started astern in three seconds; going astern, they were stopped and started ahead in five seconds.—Engineer.

BOOK NOTICES

PUBLICATIONS RECEIVED.

CIGNAL SERVICE NOTES:

No. VI. Report on Wind Velocities at the Lake Crib and at Chicago. By H. A.

No. VII. Variation of Rainfall West of the Mississippi River. By H. A. Hazen.

No. VIII. The Study of Meteorology in the Schools of Germany, Switzerland and Austria. By Frank Walds.

No. X. Report on the Lady Franklin Bay Expedition of 1883. By Lieut. Ernest A. Gar-

ton. Washington: Signal Office.
From Mr. James Forrest, Secretary of the Institution of Civil Engineers, we have received the following papers of the Institution:

The Adoption of Standard Forms of Test

Pieces. By William Hackney, A. I. C. E. Wood-working Machinery. By James Bernard Hunter.

Speed on Canals. By Francis Roubillac

Conder, M. Inst. C. E.

Two Applications of Calculation to the Resistance of Materials. By Charles Antoine, of

The Theory of the Dynamo-Electric Machine. By Randolph Clausius, Hon. M. Inst. C. E.

Abstracts of Papers, Vol. 74, part 4. Monthly Weather Review for April. Wash-

ington: Signal Office.

School of Mines Quarterly for May. Report to U. S. Commissioner of Fisheries; with Plans for the Fishways of the Great Falls

of the Potemac. By M. McDonald.

Report of the Board of State Engineers of the State of Louisiana for 1882–83. Baton Rouge: State Printer.

YMBOLIO ALGEBRA, OR THE ALGEBRA OF ALGEBRAIO NUMBERS. By PROF. WM. CAIN, E. Van Nostrand's Science Series. No. 73.

This essay will prove of special interest to teachers and pupils of elementary algebra, the vexed question of negative quantities being the single topic of the first half of the book. Nothing could be clearer than the author's exposition of the system of symbols which avoids the difficulties encountered by students or teachers who are hampered by arithmetical conceptions.

A second essay in the same book relates to the methods of geometry, and will prove equally serviceable and interesting to the same class of readers. The principles discussed are not so rudimentary in character, but the explanation is of such a nature that students of elementary mathematics may read it with profit; indeed, these essays form a part of the author's course as an instructor in the Military Academy of Charleston, S. C.

TESTING MACHINES: THEIR HISTORY, CON-STRUCTION AND USE. BY ARTHUR V. AB-Van Nostrand's Science Series, No. 74. New York: D. Van Nostrand.

The testing machine is a modern invention. Economy of material is a matter of recent Only modern engineers have applied methods of calculation to determine the limits within which they can successfully build; the limits involving safety and durability on one hand, and clumsiness and wastefulness on the other. The data for such calculation can be properly furnished only by the testing machine.

The development, construction and use of such machines is graphically set forth in this little essay. Evidence of careful study of the subject is manifest throughout the book.

The illustrations are numerous and excellent.

PEPORT OF THE CHIEF OF ORDNANCE TO THE SECRETARY OF WAR FOR THE YEAR 1883. Washington: Government Printing Office.

Like ordinary official reports, this one presents its chief value in its appendices. "Appendix 9" there is nothing that is intended to be read probably by anybody. From Appendix 10 to Appendix 42, inclusive, there is much relating to systematic trials of materials and of guns that will be regarded with interest wherever the art of war is a subject of study.

There are many illustrations of different kinds and all degrees of excellence scattered through-

out the volume.

NTRODUCTION TO THE STUDY OF MODERN FOR-EST ECONOMY. By JOHN CROUMBIE BROWN, LL.D. London: Simpkin, Marshall & Co. Few writers have done as much to advance

the plans of preserving forests as the author of this treatise. He was one of the first to collect statistics exhibiting the full measure of the evil resulting from destruction of forests.

The general principles of preserving and restoring forests are compactly stated in this last essay. The newly-awakened interest in this subject in the United States should ensure a wide reading of it ..

MANUAL OF CHEMISTRY—PHYSICAL AND INORGANIC. By HENRY WATTS, B. A., R. S. Philadelphia: P. Blakiston & Co.

This book is designed to take the place of the well-known "Manual of Chemistry" of the late Professor Fownes. Like that widelyknown text book it presents a complete outline of chemical physics and inorganic chemistry.

A short sketch of the more important elementary bodies commences the volume. The Laws of Combination, the Rules of Nomenclature then follow, and then in order come Heat, Light, Magnetism and Electricity, which closes the first part.

Part second, which is about two-thirds of the bulk of the volume, contains Inorganic Chemistry on the familiar plan of ordinary English

text-books.

The careful and even claboration of the successive topics which gave the old book its value seems to have been carefully preserved in the present edition. In some places the new editor has failed to preserve the precision of the old book. This is especially noticeable in some of the definitions of scientific terms.

SHORT TEXT BOOK OF INORGANIC CHEM-ISTRY. By Dr. HERMANN KOLBE. Translated and edited by T. S. Humpidge, Ph. D. New York: John Wiley & Sons.

"The problem of the lecturer on chemistry," says Dr. Kolbe in his preface, "is to give his hearers an idea of chemical processes, and the most important chemical theories, without burdening their memories with a large number of mere facts, and thus to prepare them to acquire an accurate knowledge of chemistry by their own practical work.'

With this principle constantly in view this text book has been carefully prepared. Chemical reactions and processes are given only to illustrate the principle or law of combination,

the latest discoveries. The illustrations are few in number but good.

ELECTRICITY: ITS THEORY, SOURCES AND APPLICATIONS. By JOHN T. SPRAGUE, M. S. F. E. London and New York: E. &. F. N. T. E.

Judging from the numerous inquiries which have been made, many of our readers will be glad to hear that the long-promised second edition of this work is now issued. The new edition is greatly enlarged, the 384 pages of the first having now grown to 650, forming a substantial volume of well and closely-printed matter, inclosed in a handsome binding. We see that all that was in the first edition is reproduced, though with some rearrangement and revision; therefore, the work retains the special character which distinguishes it from all other electrical books, and which rendered it so welcome and useful to that great class of students of electricity who are not familiar with mathematical formula, and either dislike, or can not master the abstract theories of the text books. This is indicated by a statement in the preface: "There are two electricities known to the scientific world: the electricity which exists in nature, and the electricity which, created by mathematicians, exists chiefly upon the blackboards of the professor's classroom. It is the first of these electricities which this work endeavors to elucidate." But this second edition carries the reader further in the direction of mathematical electricity than the first one did, as the section in Measurement fully explains the centigrade system, and we note that the term "potential" is not repudiated as in the first edition, though not allowed to displace the simpler "electromotive force." Its meaning also is fully discussed, and its relation to energy explained.

The chapter on static electricity is considerably extended, particularly in connection with inductive capacity, and the latest improve-ments in the Voss and Wimshurst machine are The chapter on batteries has not described. been much altered, as every useful form was already fully explained: but a full description of secondary batteries is added to it, derived from the series of articles which appeared in our pages, and in which all the most trustworthy information on the subject was fur-

nished.

The chapter on measurement is largely rewritten, and we see that Mr. Sprague has included in it the results of his own investigations in galvanometry and the mode of graduation he has devised for his patent galvanom-eters, which will no doubt be of interest to The sections on electrolysis and metalmany. The sections on electrolysis and metal-lurgy have undergone little change—indeed, they were already so complete that there was little need for change.

The original chapter on Lightning has been extended into a more general one on Terrestrial Electricity, in which we see a statement which will probably be challenged. viz., that "there is good reason to believe that nothing resembling electrical action occurs across space," and that neither the earth nor any of the other orbs The science as elucidated is in accord with have a static electric charge; this doctrine would be inconvenient for the many theorists who can now utilize electricity as an explanation for anything they do not understand; but it is defended by the argument that if such charges existed "gravitation could not be a constant force." A very full description is given of the principles of dynamo-machines, including the principle of compounding and the use of the "characteristic curves," their efficiency as also that of electro-magnetic motors, and the cost of current and work derived from them.

A chapter of 34 pages on electric lighting is entirely new, and contains a great deal of information as to the nature of light and its relation to electricity, as well as the practical processes and apparatus employed, and the cost of obtaining the light, as to which the sound remark is made that this is one of those matters in which a little knowledge is a dangerous

thing.

Telephones, radiophony, the induction balance, and the latest discoveries are fully explained in one chapter, together with a sketch of the leading principles of thermo-electricity, and the dictionary of terms, which gives convenient definitions for reference, concludes a work which may fairly be described in the words of an American professor, quoted among other critics: "The principles of the science and the operations of its laws are given with a perspicuity and fullness of exposition rarely to be met with. It is not too much to say that the laws of the correlation of the forces are here worked out in a manner exceptionally im-The work pressed with originality. . is pregnant of valuable thought, and should be read by all who seek to get a firm grasp upon the fundamental principles of the science."

An ample index is supplied, and we note that our suggestion in reviewing the first edition has been adopted, and that a copious table of contents has been added to the present edition.

English Mechanic.

A BSOLUTE MEASUREMENTS IN ELECTRICITY AND MAGNETISM. By ANDREW GRAY, M.A., F. R. S. E., Chief Assistant to the Professor of Natural Philosophy in the University of Glas-

gow. London: Macmillan and Co.

A want is felt in physical laboratories for a work that may serve a student as a guide through the various departments of electrical and magnetic measurements. Kohlrausch's "Introduction" contains much useful information, but it is put together in a manner that is not always clear and satisfactory. Kempe's "Handbook" is very good for the special purpose for which it was written, for it meets in a complete manner all the requirements of electric telegraphy. It is expected that the forthcoming volume by Professors Mascart and Joubert will in some measure supply our deficiency.

Mr. Gray's book is not introductory; it presupposes a good acquaintance with the laws of electrical and magnetic quantities, and the methods of measurement in general use. Nor is it a complete treatise; it was written for the specific purpose of giving, by a few wellchosen and typical measurements, a clear account of the absolute system of units now uni-

versally adopted.

As illustrating magnetic measurements, we have a detailed explanation of the Gaussian method of determining the horizontal component of the earth's force. This naturally leads to definitions of the magnetic units and elements.

The theory of the ring tangent galvanometer follows, nothing, however, being said of the double-coil arrangement of Helmholtz now generally adopted in standard instruments. In developing the theory of the several instruments described, the author does not hesitate to discard unwieldly elementary methods, and uses where necessary the more rapid and powerful formulæ of the integral calculus.

Due prominence is given to the comparatively new instruments—the graded galvanometers—of Sir William Thomson. The theory of each is explained and several ways are described by which they may be graduated and their accuracy easily verified at any subsequent

ime.

The comparison of resistances occupies a chapter of thirty pages, in which are discussed such important matters as the sensitiveness of the Wheatstone bridge and Kirchoff's modified form of it, the elimination of the effects of self-induction, the calibration of wires, the measurement of high resistances, the insulation of the electrometer, and the internal resistance of batteries.

We notice, in connection with this chapter, that no reference is made to Professor Forster's elegant method of calibrating wires, or to the various condenser methods for determining what is called the resistance of a battery.

Another chapter of the book treats of the development of energy in the various parts of an electric circuit. It contains much useful information about many points relating to dynamos and electric motors which one would look for in vain in text-books published a year back. This information is obtainable from first sources only, being scattered over the proceedings of many societies; and Mr. Gray has done a serviceable work in giving briefly the conclusions of the more important investigations that have been carried on. The efficiency of machines is defined, its relation to speed and resulting potential pointed out, a convenient form of ergometer is described, and a sketch of the theory of alternating current, machines is given including the effects of self-induction.

This latter theory is confessedly a difficult subject, and one could not expect of Mr. Gray more than a brief reference to the several variables which lead up to that very complex integral, viz., the current from a dynamo or an alternating current machine.

The concluding chapters deal with the measurement of intense magnetic fields, magnetic permeability and susceptibility, and the various electro-static and electro-magnetic

units.

If we had to point out any part of this excellent little book which appeared to us wanting in clearness, we should indicate the early paragraphs of Chapter X. We think a clearer exposition is possible of the meaning and methods of measurement of the efficiency of dyna-

mos and motors, and also of the precise conditions required for rapidity and economy

of working respectively.

Unduc importance seems to be attached to the copper voltameter. We may mention that Lord Rayleigh found it unreliable for accurate measurement, and hence the adoption of the

silver voltameter for delicate work.

Mr. Gray states as the result of many careful determinations made in the University of Glasgow by Mr. Thomas Gray, that a coulomb liberates at the negative electrode, .000331 of a gramme of copper. This would make the electro-chemical equivalent e = .00331, whilst if we take the e of silver as determined quite recently and with extreme care both by Lord Rayleigh and by Kohlrausch as .01118, the electro-chemical equivalent of copper as deduced therefrom would be .00344.

To one who has already a good knowledge of electrical matters generally, and some experience in a physical laboratory, the work of Mr. Gray will be of great help. Written by a man who is practically familiar with his subject, and who enjoys the advantage of everyday intercourse with Sir William Thomson, it is replete not only with theoretical information, but it is also very suggestive of "means and

ways."-Engineering.

MISCELLANEOUS.

THE ELEOTRO-CHEMICAL EQUIVALENT OF SILver.—A very careful and important determination of the electro-chemical equivalent of silver has been made at the Observatory of the Physical Institute of Wurzbourg, and the results are that an ampere current flowing for a second, or a coulomb of electricity deposits 1.1183 milligrammes of silver or 0.3281 milligrammes of copper, and decomposes 0.09328 milligrammes of water, a result agreeing closely with that of Lord Rayleigh recently communicated to the Physical Society. An ampere therefore deposits 4.0259 grams of silver per hour; Kohlrausch's value is 4.0824, a value hitherto accepted universally. This value is so useful in measuring electric currents with accuracy, and free from the disturbances of magnetism, &c., that it is eminently satisfactory to find the German value agree with that of Lord Rayleigh, which will probably be adopted by English electricians.

When a casting is very thin, even if of soft grey pig, it is often as hard, even though run in sand, as if cast in a chill. Such castings may be annealed, so that the surface may be worked, by putting them in boxes and raising the temperature to redness. In the case of gray iron the castings are surrounded with coarse sand, and heated for forty-eight hours; but in that of white iron they are surrounded by a mixture of one part of sal-ammoniac and twelve parts of hammer scales, and heated for twenty-four hours. This length of time is sufficient to soften the skin; but if the operation be continued for a week the castings will become malleable.

The following formula has been given for a convenient ink for marking, by means of a stamp, textile articles that have to be washed: Twenty-two parts of carbonate of soda are dissolved in 85 parts of glycerine, and triturated with 20 parts of gum arabic. In a small flask are dissolved 11 parts of nitrate of silver in 20 parts of officinal water of ammonia. The two solutions are then mixed and heated to boiling. After the liquid has acquired a dark color, 10 parts of Venetian turpentine are stired in it. The quantity of glycerine may be varied to suit the size of the letters. After stamping expose to the sun or apply a hot iron.

A New Standard Light.—Her Heffner-Alteneck has suggested a new standard light for photometric purposes, which promises, to be very simple and effective in operation. The light is produced by an open flame of amylacetate burning from a wick of cotton fiber which fills a tube of German silver 1 in, long and 316 mils, internal diameter; the external diameter being 325 mils. The flame is 1.58 in. high from top to bottom; and it should be lighted at least ten minutes before using the light for testing. A cylindrical glass chimney surrounds it to ward off air currents. About 2 per cent. of the light is absorbed by the glass. The power of the flame is that of a standard English candle; and experiments have shown that amylacetate, which besides is not expensive, is the best fuel for steadiness and brilliance. Neither substitution of commercial amyl-acetate for pure, nor the use of wick of cotton thread for loose cotton fiber alters the illuminating power; but the wick should be trimmed square across the mouth of the tube, for if it project and droop the illuminating power is increased.

A STANDARD THERMOPILE.—Dr. G. Gore, F.R. S., has invented an improved thermopile for measuring small electromotive forces. consists of about 300 pairs of horizontal, slcnder, parallel wires of iron and German silver, the former being covered with cotton. are mounted on a wooden frame. About $1\frac{1}{2}$ in. of the opposite ends of the wires are bent downwards to a vertical position to enable them to dip into liquids at different temperatures contained in long narrow troughs; the liquids being non-conductors, such as melted paraffin for the hot junctions, and the non-volatile petroleum, known as thin machinery oil. The electromotive force obtained varies with the temperature; a pile of 295 pairs having a resistance of 95.6 ohms at 16 deg. Cent., gave with a difference of temperature of 100 deg. Cent., an electromotive force of .7729 volts, or with 130 deg. Cent. an electromotive force of 1.005 volt. Each element, therefore, equaled .0000262 volt for each degree Cent. difference of temperature, On having been verified with a standard voltaic cell the apparatus becomes itself a standard, especially for small electromotive forces. It is capable of measuring the $\frac{1}{34861}$ part of a volt. For higher electromotive forces than a volt, several of these piles would have to be connected in series. The fractional electromotive force is obtained by means of a sliding contact which cuts out so many pairs as is required.

VAN NOSTRAND'S

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NO. CLXXXVIII.—AUGUST, 1884.—VOL. XXXI.

EXPERIMENTS ON THE EFFICIENCY OF INCANDESCENT ELECTRIC LAMPS.

By HORACE B. GALE, Natick, Mass.

Contributed to Van Nostrand's Engineering Magazine.

II.

METHOD OF COMPARING CURRENTS.

There were thus two simultaneous measurements of current to be made. As there was, however, but one reliable ammeter at the writer's disposal, an arrangement was devised by means of which the strength of two electric currents—for example, the current through the lamp and the current through a resistance coil in derivation with the lamp—could be compared with each other by means of the Wheatstone's bridge.

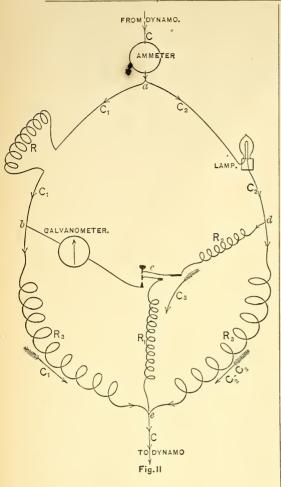
As this method is the most accurate one known to the writer for comparing strong currents of electricity, and as it requires no special apparatus except an ordinary Wheatstone's bridge, it will be described in full, in the hope that other experimenters may find it useful. arrangement will be understood from the accompanying diagram. Fig. 11.

The current C from the dynamo passes through the ammeter, and divides at the point a between the two branches abe and ade of the circuit, one portion of the current whose strength is denoted by C, passing through the resistance coil R, and the other, C2, passing through the lamp, which stands in its place at the end coils of heavy copper wire of small resist- the resistance between those points.

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ance, but exactly equal to each other; the resistance of each being denoted by R₃. After traversing these coils, the currents C, and C, unite at e, and return to the dynamo. dc and ce are two arms of the Wheatstone's bridge, whose resistances are marked R_1 and R_2 . The bridge proper, containing the galvanometer, is from b to c, the circuit through it and the resistance coils R, and R, being closed in the ordinary manner by a double key, at c. When the key is closed, a small portion of the current C₂ is shunted around de through the coils R₂ and R₁ of the bridge. This current is denoted by Then the current passing through the portion de of the circuit is $C_{\circ} - C_{\circ}$, as indicated in the diagram.

In using the apparatus, the arm R, is made a certain fixed resistance, say 1,000 ohms. The resistance R, is then adjusted, until, on pressing down the key, no current passes through the galvanometer. The points b and c are then at the same potential. It follows that the difference of potential from b to e is the same as the difference of potential from c to e. But the difference of potential, or the electromotive force, between two points of a of the photometer bar. be and de are two circuit is the product of the current and



Therefore
$$C_1R_3=C_3R_1$$
, or $C_3=\frac{C_1R_3}{R_1}$.

Our purpose, it should be remembered, is to ascertain for each lamp the variation in candle-power and current strength as the electromotive force is increased; for which object it is necessary to vary the candle-power by a series of steps, and take simultaneous observations of the current and electromotive force at every point. Knowing, in each case, the value of the total current, C, if we can find the ratio between the currents C, and C, traversing the two main branches of the circuit, we shall have, not only the current flowing through the lamp, C, butelectromotive force.

Our object is now to find the ratio between the currents C, and C2. It is evident that the electromotive force from d to e is equal to the sum of the electromotive forces on dc and ce; or using instead the products of the currents and resistances on these branches, we have

$$(C_2-C_3) R_3 = C_3 (R_2+R_1)$$

Substituting for C_3 its value $\frac{C_1R_3}{R}$ pre-

viously found, we have

$$\left(C_{2} - \frac{C_{1}R_{3}}{R_{1}}\right) R_{3} = \frac{C_{1}R_{3}}{R_{1}} \left(R_{2} + R_{1}\right)$$

Clearing of fractions,

$$C_2R_1-C_1R_3=C_1R_2+C_1R_1$$

Transposing and combining,

$$C_2R_1 = C_1 (R_1 + R_2 + R_3)$$

or

$$\frac{C_{_{2}}}{C_{_{1}}} = \frac{R_{_{1}} + R_{_{2}} + R_{_{3}}}{R_{_{1}}}$$

When the resistance R_s of each of the equal coils of large copper wire is so small in comparison with the other resistances that it may be neglected, we may write

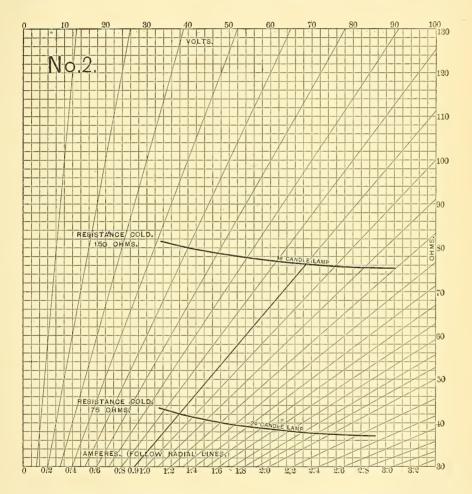
$$\frac{C_2}{C_1} = \frac{R_1 + R_2}{R_1}$$
.

Expressing this equation in words, we say that the current passing through the lamp is to the current passing through the resistance coil R, as the sum of the resistances of the fixed and variable arms of the bridge is to the resistance of the fixed arm.

Having thus found the ratio between the currents in the two branches of the circuit, and knowing also by observation of the ammeter, the value of the total current C, which is the sum of the two portions C, and C, it is an easy matter to find the absolute value of the current in each branch of the circuit. The electromotive force on the branch abe is then computed by multiplying the resistance of that branch by the current passing through it, and this gives us the electromotive force between the terminals of the lamp, after deducting the trifling amount necessary to overcome the resistby multiplying the resistance of the ance of the wire in the branch ade. The branch abe by C₁—we may obtain the horse power expended in the lamp is then found by multiplying together the current, and dividing the product by 746.

The resistance R₃ of each of the equal coils be and de was in this case only 0.424 ohm, and the fixed arm of the in the fifth decimal place, its use was an unnecessary refinement.

values of the electromotive force and the through the coils of the bridge, we may, by adjusting the resistance of the fixed arm, reduce the current to a strength just sufficient to obtain deflections of the galvanometer; third, while the current bridge was generally made 1000 ohms. passes constantly through the lamp, the The value of R, was not neglected in the circuit through the bridge is closed only calculations, but as the error that would when the key is depressed. It was found have been caused by its neglect would be that, with ordinary care, the ratio of two currents could be thus ascertained accurately to four decimal places.



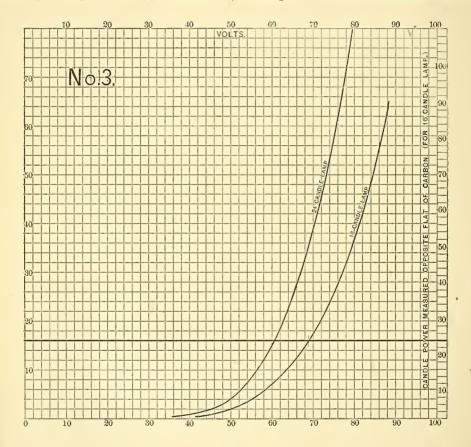
The above method of ascertaining the electromotive force and current of an incandescent lamp possesses several practical advantages over any method in which the lamp itself forms one arm of a Wheatstone's bridge. First, no special

PRECAUTIONS OBSERVED.

The accuracy of this method of comparing currents evidently depends upon the exact equality of the resistances of the two coils be and de. They consisted of number six copper wire, covered with apparatus is required; second, instead of paraffined cotton braid. Such wire will passing the entire current constantly carry fifty amperes without warming perceptibly, and as the currents used in ly through it. The current traversing these experiments rarely exceeded two it never exceeded one ampere, and was eter so sensitive that a variation of $\frac{1}{100}$ of one per cent. was perceptible. Their per cent. equality was again tested at the close of

amperes, there was no danger from unequal heating of the two coils. Before warm perceptibly. This coil was also arbeginning the tests, these coils were ad-ranged so that it could be instantly taken justed to equality by means of the out of the circuit and connected with the Wheatstone's bridge, the final adjust-bridge, and its resistance measured at inment being made by a sliding contact tervals during the progress of a test. It resting on the wire, with the galvanom- was found that the error due to the heat-

This part of the work was carried on at



the work. To insure that the two coils times by two observers, one of whom obshould always be at the same temperaserved the ammeter and the bridge, while ture, they were wound on a frame into a the other took simultaneous observations single loose coil.

ance of the coil R should not be altered reading first the ammeter and the bridge, by the passage of the current. This coil then the photometer, and then, to insure consisted of about 200 ohms of number that no change had occurred, again readeighteen German silver wire. It was ing the ammeter and bridge. wound with silk, and hung loosely over a frame, so that the air could circulate free- In these, and all the observations with

with the photometer. At other times It was also important that the resist- the writer alone took all the observations,

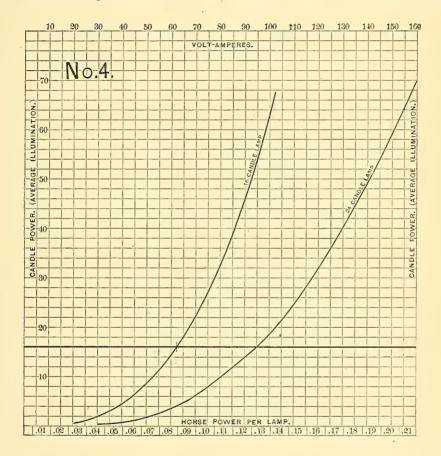
THE PHOTOMETRIC TESTS.

readings could be made quite exactly.

this kind of work being impracticable power was gradually increased, and imfor various reasons. In order to obtain mediately following it by another series

the photometer, five or more readings a slow variation, due to the gradual were taken at every point, and their crusting over of the wick, and to differmean used as the true reading. After ences in the temperature of the room at considerable practice, these photometric different times. The error from these adings could be made quite exactly.

In these measurements, a Carcel lamp, the variation in the candle power of each causes was eliminated, as far as concerned burning colza oil, was used as a standard individual lamp, by taking always a series of light, the employment of a candle for of observations in which the candle as steady a light as possible from the Car- in reverse order in which the candle



diaphragmed off, and only the middle, or least variable portion, was used as a average of about ten candle power.

like that of a candle, and would remain lamps. practically constant during a single series

cel, the top and bottom of the flame were power was decreased to the starting point.

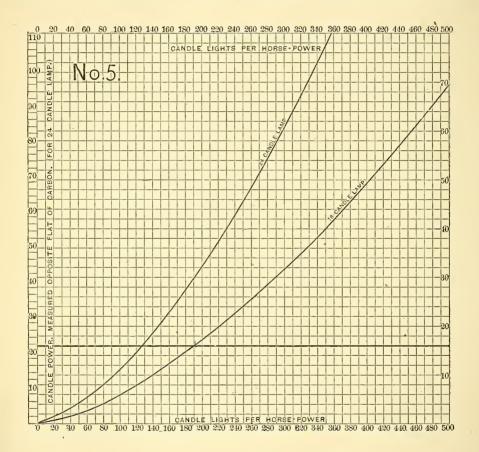
The results of these observations, then, standard. The width of the aperture while showing accurately the relative was adjusted so that the lamp gave an changes in the candle power of each lamp for given variations in electromotive force Though the light of the Carcel lamp and current, could not be implicitly relied was not subject to sudden fluctuations, upon for comparisons between different

Accordingly, while the electrical quanof observations, there was nevertheless tities were here obtained in absolute

measure, it was not attempted in this part of the work, to measure candle and burned very nearly 120 grains per power with absolute accuracy, but merely hour. to obtain the data from which a curve could be constructed for each lamp show- gives us the absolute candle power and ing on some arbitrary scale the variation in candle power with different electromo- the curve of this individual lamp. tive forces.

obtained from Tufts Brothers, Boston,

The average of the above observations electromotive force for a single point on get the entire curve into absolute meas-The remaining problem was to reduce ure it is simply necessary to change the all these curves to the same absolute scale of the diagram to conform to this scale. One of the lamps was next run measurement. Having done this, we have



candle power, current, and electromotive powers. The candle was hung on the arm of a balance made for the purpose, and the time required for the consumption of each twenty grains was noted, and the duced to the same absolute scale by a ard candles were used, all of which were at opposite ends of the photometer.

for some eight hours at about its rated two correct curves for a single lamp, in candle power, and very carefully com- which abscissas represent volts, and ordipared with a standard candle, measure- nates represent, in the one curve, amperes ments being constantly taken of the of current, and in the other, candle

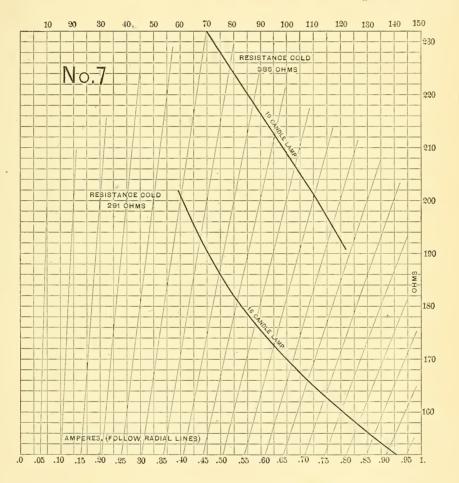
DIRECT COMPARISON OF EFFICIENCIES.

proper corrections made. Several stand- system of direct comparisons of the lamps

one end of the photometer bar, a lamp bridge method. Whose curves of candle power and curphotometer.

The method consisted in placing at through each branch measured by the

By thus obtaining accurately the ratio rent had been already obtained in abso- of the currents flowing through two lute measure, and at the other end the different forms of incandescent lamps, lamp whose curve was to be reduced to while they are running at a given relative that standard. The lamps were then run brilliancy, and knowing, from our previat their rated candle power, and their ous experiments the ratio of the resistrelative brilliancy ascertained by the ances of the two lamps with these given currents, the relative efficiencies of the



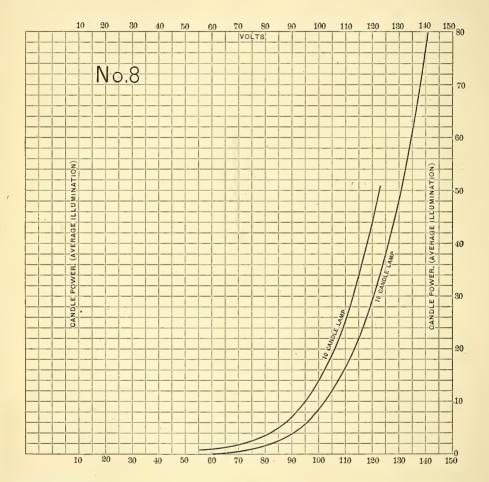
kind, or required about the same current | the absolute measurements. strength to bring them to their normal brightness, they were connected in series, tive candle power of two lamps at two and the strength of the current through given points on their respective curves, both ascertained by the ammeter. In it is simply a matter of altering the scale other cases they were placed in multiple of one diagram to bring both to the same arc, adjusted to the proper relative can- absolute standard. dle power by a variable resistance in one The great advantage of this comparabranch of the circuit, and the current tive method lies in the fact that as but

If the two lamps were of the same lamps are ascertained independently of

Having obtained in this way the rela-

one absolute determination of candle used to enable one to form a fair idea of power is made, this one can occupy a their reliability, we now pass on to congood deal of time, and be made with sider great care; and further, that as the relative efficiencies of the different lamps are ascertained by comparing the light of one lamp directly with that of another, described was a series of curves, showing, while at the same time the relative values for each individual lamp tested, the value of the currents and electromotive forces of the current strength in amperes, and are obtained by direct comparison, any the candle power, for a range of electro-

THE RESULTS.

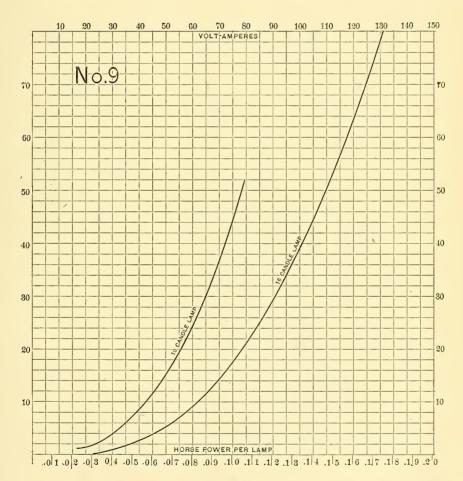


errors that may be made in the absolute motive forces, from the point where the measurements will affect all the lamps carbon is barely incandescent, to a point alike, and cannot alter the relative effi- where the lamp is giving four or five ciencies.

memoir to describe all the details and class of lamps. The method of averaging precautions against error employed in was to take lamps of the same kind,—not work which extended over a period of at the same candle power, but at the about two months.

times its normal candle power. These It is of course impossible in a brief results were carefully averaged for each Therefore, having same electromotive force, as they are ingiven a sufficient account of the methods tended to be run in practice,—and find, from the curves for the separate lamps, im lamps, and No. 7 shows the same point: the average resistances being and the curve for each lamp is so conare run in multiple arc.

the values of the candle powers and am- thing for the Edison lamps. In these peres at intervals of five volts. Then the diagrams electromotive force in volts is average of these values was taken at each laid off on the horizontal scale at the top, computed by dividing the number of structed that the height of any point on volts by the average number of the am- it represents on the vertical scale at the peres. This gives to all the quantities right the resistance of the lamp in ohms, the same mean values which they would under the corresponding electromotive have in an actual case, where the lamps force. It is also desirable to show the current which will flow through the lamp

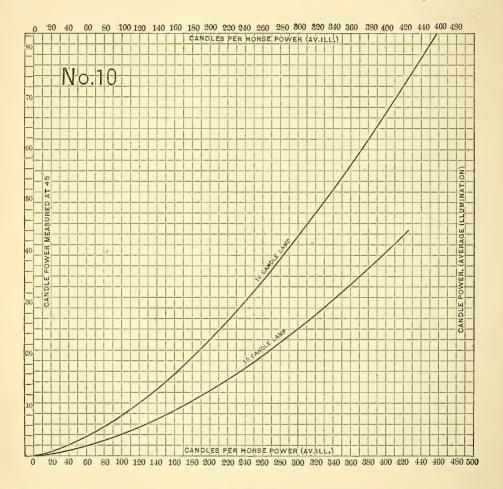


sented graphically, and are shown by the also the resistance of the carbon when a diagrams hereto annexed. The curves of given current is passing through it. We equal illumination have already been re- have, then, to express the relations of ferred to. The next curves plotted were intended to show, for each class of lamps, done by three separate diagrams: but as the relation between the electromotive the current is always equal to the elecforce, current, and resistance. Diagram tromotive force divided by the resistance, No. 2 shows these curves for the Max- it may be represented, for any point on

The average results have been repre- under a given electromotive force, and

in this case outside the limits of the diaof current on a scale of equal parts at the ables.

the curve, by the tangent of the angle tal line from that point to the scale at the included between the vertical axis of co-right; or to find the electromotive force, ordinates, and a line from the origin to follow a vertical line through the same the given point. Therefore, by drawing point to the scale at the top. In short, radial lines through the origin, (which is given any one of the three quantities, electromotive force, current, or resistance, gram,) we are enabled to lay off amperes —the other two may be found at once This device for from a single curve. bottom, thus making the same curve ex- expressing graphically the triple relation press the relation between three vari- between the principal electrical quantities the writer believes to be new, and it is



either of the curves, it is necessary only to follow a radial line from the given point down to the scale at the base of the diagram; or, starting with a certain curmotive force is again represented on the rent, follow the radial lines up to the horizontal scales at the top and bottom, corresponding point on the proper curve; and the height of any point on either

To find the current for any point on presented as one that will be frequently found convenient.

In diagrams No. 3 and No. 8 electrothen to find the resistance of the lamp curve shows on the vertical scales at each with the given current, follow a horizon-side the number of candle powers of light

which the lamp will give with the indicated electromotive force.

The resistance of a lamp is found to fall quite rapidly as the electromotive force is increased, until the carbon becomes incandescent, when the change goes on more slowly, the resistance of a lamp when giving its light being rather more than half its resistance when cold. As will be seen from diagrams No. 3 and No. 8, the candle power increases slowly at first, but afterwards with increasing rapidity, until, if the electromotive force is carried above a certain point, the carbon filament is broken.

In diagrams No. 4 and No. 9, the horizontal distance of any point on either curve to the right of the origin represents the power consumed in the lamp, expressed in horse power on the scale at the bottom, and in volt-amperes on the scale at the top. Candle power is again laid off on a vertical scale. These curves show clearly what has before been stated, i.e. that a certain amount of power must be expended in a lamp before we begin to get any light; and that the brilliancy of the light expressed in candle powers then rises more and more rapidly as the energy expended is increased.

In diagrams No. 5 and No. 10 the vertical height of any point of either curve corresponds as before to the candle power of the lamp, and the distance of the same point to the right of the origin measures, on the horizontal scales at the top and bottom, the number of candle lights per horse power which lamps of this class will furnish when running at the indicated candle power. These curves show us how rapidly the efficiency of the lamps increases as the candle power is raised.

In diagrams No. 3 and No. 5 the vertical scale at one side indicates the apparent candle power as measured opposite the face of the carbon, and that at the other side the average or true candle power. It will be observed that the Maxim 16 candle lamp, at its normal candle power (indicated on the diagram by the heavy horizontal line), gives a light equal to 22 candles opposite the face of the carbon, and that the average illumination is about 73 per cent. of the face measurement.

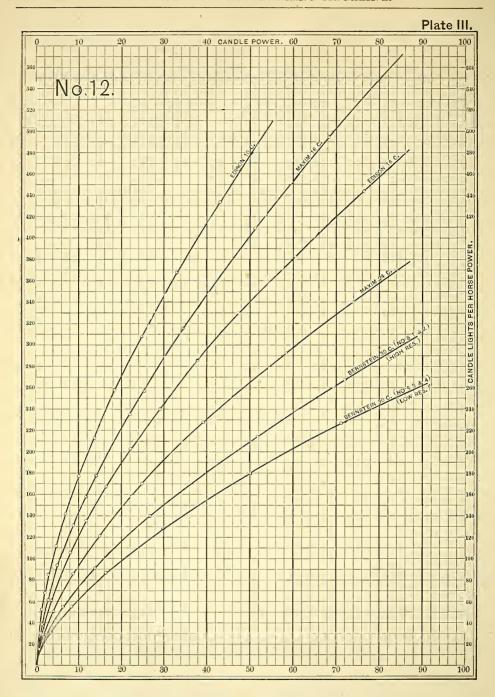
The curves in all the diagrams are son 16 candle lamps on which these tests drawn exactly through the plotted points; were made would give only about 6

the slight irregularities apparent in the curves for the separate lamps being almost wholly eliminated in the average.

In Fig. 12 the curves representing the change in efficiency of the various lamps at different candle powers are shown upon a single diagram for the purpose of comparison. Here candle power is laid off on a horizontal scale, and, for each class of lamps, the height of any point of the curve indicates on the vertical scale the number of candle lights per horse power which the lamps will give when running at the corresponding It is noticeable that all candle power. the curves have the same characteristics, viz., that the efficiency at first rises very rapidly with increase of candle power, and that afterwards, while the change goes on more and more slowly, the rate of increase in efficiency becomes at the same time more nearly uniform, or, in other words, the curve approaches to a This would indicate, that straight line. however high the temperature of a carbon filament may be raised, raising it higher will still increase its efficiency as a light giver.

It must not be inferred, because the curve of any lamp is above the rest, that this lamp is absolutely more efficient than the others; for, as already pointed out, when a lamp designed to give 10 candle power is run at, for example, 16 candle power, its efficiency becomes higher than its normal value; whereas, if a 24 candle lamp is run at 16 candle power, its efficiency falls below its normal value. Consequently, when lamps rated at different candle powers are compared at the same candle power, the lamp with the lower rating has an advantage. The only way to arrive at a fair comparison is to take the efficiency of each lamp at a point on its curve which corresponds to the rated candle power. Comparing the lamps in this way, we find that the Maxim 16 candle lamp stands highest, and the Edison 10 candle lamp next.

It should be noticed that the Edison 16 candle lamps furnished for this test were not of the same grade as those in general use for isolated lighting. The latter may be run in parallel circuit with the 10 candle lamps, each giving its own proper candle power; whereas the Edison 16 candle lamps on which these tests were made would give only about 6



candle power on the same circuit with the 10 candle lamps, when the latter were at their normal brightness. By refering to diagram No. 8, it will be apparent that at the same electromotive lamps, which, as will be seen from the

table of resistances previously given, averaged about 291 ohms when cold. Measurements afterwards made by the writer upon ten 16 candle lamps, collected from various plants of the Edison Company throughout New England, showed the following results:

RESISTANCE COLD.

Lamp	No.	1	.	 	.162	Ohms.
"						"
66	66	3		 	.163	**
64	64	4		 	.186	"
"	"			 		"
" "	66			 		"
"	666			 		"
66	66	8		 	.186	
"	66			 		"
	" 1			 		

Average resistance.......182.3 Ohms.

These lamps averaged 16 candle power at 95 volts, the same electromotive force required to bring the 10 candle lamps to their normal brightness, and were therefore evidently the grade of lamps intended to run on the same circuit with the latter. They were not obtained in time to make a complete test at all candle powers, but measurements were made at the rated candle power, which gave the following average results.

Edison Lamps at 16 Candle Power.

Electromotive force	. 95.	volts.
Current strength		
Resistance		
Volt-amperes	. 87.4	
Candle lights per horse power		
Lamps per horse power		1

The following are the figures for the Maxim 16 candle lamps.

MAXIM LAMPS AT 16 CANDLE POWER.

Electromotive force	68.9	volts.
Current strength	0.9	ampere.
Resistance	76.5	ohms.
Volt-amperes	62.2	
Candle lights per horse power1	92.	
Lamps per horse power	12.	

The results of these experiments indicate that the essential factor in the efficiency of an incandescent lamp is not high resistance, but high incandes-cence. The Maxim lamps, which The cence. displayed the highest efficiency, gave a. slightly whiter light than the others, showing that the carbons were heated to a higher temperature; though their resistance was lower than that of the Edison lamps. The fact that a low resistance filament is usually coarser than one of high resistance would tend to make it endure equally well at a higher temperature.

TESTS OF RUTLAND AND WASHINGTON COUNTY SLATES:

By J. FRANCIS WILLIAMS, C. E., B. S.

Contributed to Van Nostrand's Engineering Magazine.

were made June 7th and 9th, 1884, in the tion. mechanical laboratory of the Rensselair The experiments marked "compresselair Polytechnic Institute, Troy, N. Y., on a sion" were made upon blocks about one 50,000 pound testing machine made by Tinius Ölsen.

Marbleized Slate Co., of Fair Haven, Vt.

ured on a micrometer measuring appara- machine. tus, and the size in each direction recordupon did not differ more than 2 or 3 and gave results about one-fifth larger

The tests given in the following tables hundredths of an inch in a normal sec-

square inch in section and 11 inches in height. In the cases marked "wood" The purple and green specimens were blocks of wood $1\frac{1}{2} \times 1\frac{1}{2} \times 1\frac{1}{4}$ inches were from Fair Haven, Vt., and the red from used as cushions, one above and one be-Granville, N. Y. They were cut and low the specimen, they were of soft wood smoothed by the Fair Haven Marble and and were so placed that the grain did not run in the same direction in the two Before making each test, the piece pieces, and thus there was no tendency under consideration was carefully meas- of the blocks to become crooked in the

With those marked "paste-board," ed. The results were recorded as press-book-binder's board was used in pieces of ures per sq.inch. The pieces experimented $1\frac{1}{2}$ $\times 1\frac{1}{2}$ $\times 1\frac{1}{16}$. This is closer in texture

Tests.

Substances used as	ple.		Red.	Green.		
Cushions and Methods of the Tests.	Weight F	Remarks.	Weight	Remarks.	Weight ₩ sq. in.	Remarks.
Compressive wood """""""""""""""""""""""""""""""	18700 18170 { Cr 24760 12640 9860 18430 10480	1 seam rack 16010 2 seams rack 17370 1 seam	14390 13535 14580 14590 { 18160 21310 18380 10190 4850	crack 11220 1 seam crack'd at 12440 1 seam	13760 12520 17420 17930 16840 18060 8040 5150	2 seams 2 seams 1 seam 1 " {crushed at {op. angles}}. 2 seams
" on side-wood.		tion1" \times 1½" 2 seams	} 24030	Section1"×1½"	17760	{crack 16700 { 1 seam

Tests—Continued.

Method of Test and Length		Purple.		Red.	Green.		
of Beam.	Weight. Center Load.	Number and Remarks.	Weight. Center Load.	Number and Remarks.	Weight. Center Load.	Number and Remarks.	
Bending 6 in. span		(1.) (2.) split along (3.) (4.)	1100 450 1875 2250	(1.) 1 seam (2.) (3.) bad seam (2.) no seam (2.) (1.) 1 seam	950 775 1025 1825 2400 16020	(1.) (2.) small seam (3.) (2.) (3.)	

RESULTS OF THE ABOVE TESTS.

Compression, wood	24760 13860 10260 1200 2400	" 1 " 9 " 9 " 1	. 14170 . 18110 . 10190 . 4850 . 770 . 1710 . 17730	" 4. " 1. " 3. " 3.	17560 8040 5150 910	No. of specs.	1. 3. 3. 3. 3. 3. 2. 1.
" on side			24030		17760		1.

than the wood, and I should recommend that all experiments with stone be made with such cushions.

In the preceding cases the blocks have the case marked "on side" they were

specimen then had an area of section of $1\frac{1}{2}$ square inches. This was not reduced to inch square.

Those tests marked "no cushion" were made on specimens which had particularly smooth and parallel upper and lower surfaces, and the elastic limit was carefully observed. The U. R. in this case of course was low, owing to the unequal distribution of pressure over the sur-

The beams tested were an inch in section and 10 inches long. The supports point in the center, by which the pressure lence.

placed in a vertical position and the was applied was also covered with paste-

After the beam was broken with a six inch span the two portions were in some cases broken again as beams of a three inch span. This is indicated by the numbers placed in brackets after the breaking weight. The first three being numbered consecutively, and those which are used a second time being designated by the same numbers that they had when first broken. These, of course, were broken with their cleavage planes horizontal.

The last specimen was broken as a long were placed 6 inches apart and were cov-column with the cleavage planes vertical. ered with paste-board so as not to cut It stood more than the small blocks. the extreme fibers of the beam. The crushed and broke with considerable vio-

A NOTE ON THE LONG COLUMN QUESTION.

By WM. H. BURR.

Contributed to Van Nostrand's Engineering Magazine.

It is not a matter of surprise that Prof. Robinson should take exception to my criticism of his long column formula, or that Mr. Weston should desire to give to the immense amount of labor, involved in the computation of his tables, a character other than that of wreckage. After the lapse of so much time, one would suppose that some new point of demonstration would have been developed, or, at least, that something tangible would have been said. It is also a little remarkable that Prof. Robinson makes no attempt to strengthen the points in his analysis which I attacked. Hence, it may be supposed that he considers them hopelessly overthrown—one point, at least, on which we agree. I had also hoped that he would render a lucid explanation of the fact that his "rational" formula gives a curve convex upward within the limits, for which experiments give a curve concave upward. (See Magazine for Nov. 1883.) But as he omits the explanation and stoutly maintains that his formula is certainly, truly, and incontestably "rational," we are left to infer that the results of the tests are unquestionably irrational, and that the upward concavity of the curve is simply and only an evidence of the original

and "total depravity of inanimate things" which has from time to time been hitherto observed under proper circumstances.

But in order to come to a more detailed consideration of Prof. Robinson's last article, his analytical positions will first be examined while subsequent attention will be applied to experimental matters.

In the first place he proposes to give a new demonstration of his formula without the slightest reference to Euler's, by considering the neutral curve of the column a sinusoid!!!

As a result, in the April (1884) number of this Magazine, page 184, he finds the following value of the radius of curvation:

$$\rho_1 = \frac{l^2}{\pi^2 y_1} \qquad . \qquad . \qquad . \qquad (d).$$

Eq. (d), it is to be particularly observed, is supposed to be very different from Euler's formula.

Now, in a little book published in 1882, "Strength of Wrought Iron Bridge Members, by S. W. Robinson, C. E.," "an authority which my opponent will doubt-less accept as sound," on page 84 is found Euler's formula:

$$\frac{\mathbf{T}}{\mathbf{E}\mathbf{I}_{1}} = \frac{\pi^{2}}{l_{1}} \qquad . \qquad . \qquad . \qquad (1);$$

common theory of flexure;

$$\frac{\mathrm{EI}}{\rho} = \mathrm{T} y_{_{1}} \qquad . \tag{2}$$

The subscript 1 has been introduced in egs. (1) and (2), in order to make the notation uniform with eq. (d).

If the value of ρ_i be taken from eq. (2) and inserted in eq. (d), then will result:

$$\frac{\Gamma}{EI} = \frac{\pi^2}{l^2};$$

which is Euler's formula, and identical with eq. (d). In reality, therefore, Prof. Robinson has given in his sinusoidal method simply "a new toot on an old horn." Can it be possible that he was ignorant of the fact, that the use of the sinusoid simply meant the use of the common theory of flexure in another form, only, than Euler's formula?

Since his "new demonstration" is thus seen to involve Euler's expression for the resistance of a long column, another "new demonstration" from the same source is now in order, and it will be awaited with

After having vainly endeavored to shut Euler's formula out of view, by heaping over it considerable unnecessary sinusoidal analysis, Prof. Robinson then subjects the "classical" formula

$$\mathbf{M} = \frac{\mathbf{RI}}{d_1} = \frac{\mathbf{RA}k^2}{d_1}; \qquad . \tag{3}$$

to some most unhandsome treatment. We are told, on page 285, that R is the modulus of rupture for bending and that, hence, a beam will sustain the least load in that plane in which d_1 is greatest. Now I am aware that Prof. Robinson is not alone in that impression, though it is most erroneous. As a matter of fact, eq (3) is an equation deduced in the mathematical theory of elasticity in solid bodies, and has no "rational" connection whatever with the failure of beams or material. It is based upon the hypothesis of perfect elasticity, and is merely another form of $\frac{\mathrm{EI}}{\rho}$, R÷ d_{τ} representing E÷ ρ or the inten-

sity of stress at unit's distance from the

neutral surface.

and on page 93, the usual equation of the mined by experiments on the failure of beams, it ceases to have any rational or analytical meaning, though it is thereby made of inestimable value to engineering practice. Prof. Robinson handles this part of the matter with that freshness and naiveté which is so characteristic of unconcious lack of knowledge, and it is useless to carry this part of the discussion any farther until he informs himself more thoroughly on some of the more fundamental portions of the theory of flexure. I would refer him to C'ebsch's "Die Theorie der Elasticitát Festr Körper," where he will find an admirable treatment of the subject.

Prof. Robinson's reference to the Watertown tests of Phœnix columns scarcely agrees with the facts as given in the copy of the Trans. of the Am. Soc. C. E. now before me. As nearly as can be learned from that publication, Nos. 1, 4, 5, 7, 8, 12, 13, 16 failed in the plane of two flanges, while Nos. 2, 6, 9, 10, 11, 14, 15, 17 gave way in the direction of the barrel between the flanges—an equal number in each direction—while the remaining 6 cases are doubtful. These results therefore show that a Phœnix column is equally liable to fail in any direction—a conclusion which has been verified by other experiments at Phœnixville as well as by a proper consideration of the theory. Prof. Robinson's error lies in considering R as separate from $1 \div d$,; he should consider $R \div d$, as a single quantity.

The old paradox of the triangular beam may be properly used by a youthful instructor to impress his first class with the mysteries of the resistance of materials, but it is good for nothing else. Such a beam is just as strong as, but no stronger than, the trapezoidal one. Its fibers begin to rupture at an earlier stage of loading, but the ultimate load held, is

exactly the same in both cases.

We now come to the experimental portion of the April paper, and we find in looking over Prof. Robinson's application of his "rational" formula that he causes T to vary from 40,000 to 45,000, and E from about 23,000,000 to 31,000,000, in order to get a satisfactory agreement between his results and those of experiment. Now this is precisely what is done in all empirical formulas, and its necessity When R is given the signification of might be a matter of surprise in the the "modulus of resistance" and deter- present instance if I had not shown in

my first paper that his formula is simply the iron was "solid," "flat" and "Engand only a mongrel form of Gordon's; lish"!! Such a grade of metal must hence he is obliged to doctor it in passing from one form of section to another, in order to get a satisfactory approach to agreement with the results of tests.

But there are some features of his comparison of Gordon's formula with his own which ought not to be overlooked.

In the first place, while he gives to the empirical factors in his own formula such values as are needed to reach the closest agreement to experiment, he takes an antiquated form of Gordon's formula with empirical quantities which belong to a solid rectangular section in iron produced forty years ago, or more, and applies it, without change, to all forms of sections. Such a suspicious procedure can only result from either ignorance or design, and I refrain from comment.

But even with such aid the mean discrepancies of his own formula are less than those of Gordon's by only 400 or 500 pounds at most,—an insignificant amount for such a matter. In fact a truthful presentation of the table at top of page 288 of the April No. would probably turn the balance in favor of Gordon's formula. In that table there is a column headed "New Formula," with the evident design of conveying the impression that the results of that column come from his own formula, though an incidental explanation is given in the text. The upper five values of the column in question (nearly one-third of the whole) are the results of computation by Euler's formula, and not by Robinson's. To properly name such an action under the present circumstances would carry me beyond the limits of propriety of such a discussion, and I simply give the upper part of the table as it ought to have appeared.

$l \div k$.	Experi-	New	Rankine's or
	ment.	Formula.	Gordon's Form.
643	2410	5130	2885
540	3380	6140	3956
414	4280	8050	6250
400	5630	8350	6604
311	9600	10800	9921
300	9750	11200	10290

remarkably high value of 45,000 is that the discussion. Vol. XXXI.—No. 2—8

truly possess unusual characteristics.

Reviewing the whole field, then, it appears that by dint of fitting different empirical factors to Prof. Robinson's "rational" formula, for different forms of section, results may be obtained which, on the whole, are little or no better than those arising from an unfair and improper application of an antiquated form of Gordon's formula.

In regard to Mr. Weston's paper, little need now be said. His analytical attempt to fix the safe limit of deflection is simply a futile effort to distort an equality into an inequality, and is precisely the same feature which I attacked in Prof. Robinson's original paper; and as he has since made no attempt to repair the damage, it is scarcely worth while to repeat the criticism.

Mr. Weston's appeal to the theory of flexure comes within the scope of my observations on Prof. Robinson's attempts in the same direction; and his sublime faith in the innate superiority of the new formula to the results of experiment, makes it rather useless to attempt to bring him down to a consideration of a set of experimental results. Since, in fact, he thinks (pp. 401 and 402 of May No.) that "the new formula cannot, with justice, be compared with experimental results obtained in the usual method of breaking columns," and that "it is a question whether practice would really desire the new formulas to agree with the results of experiments for ultimate strength;" also, that the "irregular agreement of experimental and computed results, when t is given a value approximately equal to the ultimate resistance, does not prove or disprove the new formula, but, on the other hand, rather weakens the confidence in the usefulness of experimental results for ultimate strength;" it becomes a serious question whether he is not only using rather a "free lance" against engineering column practice, but also taking Prof. Robinson both in flank and rear for making such desperate and questionable efforts to get even an approximate agreement between the results of tests and his own formula. I leave them to settle this question be-His reason, he says, for giving t the tween themselves and take my adieu of

THE EVAPORATIVE POWER OF ANTHRACITE COAL IN TESTS OF STEAM BOILERS.

BY WILLIAM KENT, M. E.

Contributed to Van Nostrand's Engineering Magazine.

That portion of Mr. R. H. Buel's paper ity." Moreover, as shown by M. Gruner, on the Compound Steam Engine, etc., which relates to the Steam Boiler (VAN) NOSTRAND'S ENGINEERING MAGAZINE for June) contains so many statements which are at variance with the generally received opinions concerning boiler performance and economy, that it should not be allowed to become a portion of American engineering literature unchallenged. would be difficult to discuss completely such an elaborate paper, crowded as it is with tables of figures, without occupying more space than is taken by the paper itself, but a few of the statements to which exception may be taken may be discussed briefly.

Mr. Buel states, in reference to the summary of the experiments of Messrs. Kestner and Meunier: "There are no American coals in this table, but as the best anthracite coal of the United States contains more fixed carbon than any specimen of Table XI., it is reasonable to suppose that it is at least equal in heating power to the best European coal tested by Messrs. Kestner and Meunier."

It is unreasonable to make the supposition, 1st, because there are no records anywhere published of accurate determination of the total calorific value of American anthracite by which to support the supposition. 2d, because in Kestner and Meunier's table, the Groufcheski anthracite, which contains the largest percentage of fixed carbon of any of the coals, has the lowest evaporative power but one (lignites excepted), and hence by analogy we would infer that the American anthracites having higher percentages of fixed carbon, would have lower evaporative power (per pound of combustible). 3d, because, as stated by Mr. Buel in his quotation from Gruner, "the heat of cite is not more than 14,544 thermal combustion of a body, simple or compound, is in general greater in proportion as its molecular condensation is less advanced," and "the heat of combustion air supply, or analyzing the coal or the like the specific heat varies with the dens-products of combustion, or making direct

since the diamond gives by experiment only 13,986 units, graphite 14,035, gas retort charcoal 14,485, the less dense wood charcoal 14,544, and gaseous carbon theoretically 20,186 heat units, the calorific power increasing as compactness of structure diminishes, it would be reasonable to suppose that anthracite, in which the carbon is probably as compact as in gas retort charcoal, would have a similar heating value, or about 14,500 heat units.

The writer has always in his experience in testing boilers, or in calculating the results of tests, assumed the calorific value of the combustible portion of anthracite coal to be 14,500 heat units. equivalent to an evaporation of 15 lbs. of water from and at 212°; and he has thus far seen no reason to believe that more than 80 per cent. of this heating power can be utilized under ordinary working conditions in any boiler in which the products of combustion are allowed to escape at a temperature above 350° or 400°.

Mr. Buel gives a number of results of experiments "generally regarded as being amongst the most reliable that have ever been made, all of which must be repudiated by those who believe that the maximum heating effect attainable from the combustible in the best varieties of American anthracite is 14,544 thermal units per lb., and that the average amount of air supplied to furnaces consuming American anthracite is from 25 to 30 lbs. per lb. of coal."

In the absence of any direct and conclusive evidence to the contrary, the reasons given above are sufficient for believing that the heating value of the combustible in the best American anthraunits. And any test of a steam boiler (made as ordinary boiler tests are made, without either measuring the quantity of

test of the heat lost by radiation) which shows a result which would require the heating value of anthracite to be greater than 14,544 units, must be repudiated on that ground alone, if there were no other, notwithstanding the weight of authority which is presumably due to the experiments of Isherwood, or any other engineer "generally regarded as being among the most reliable."

As to the "average amount of air supplied to furnaces consuming American anthracite" being from 25 to 30 lbs, per lb. of coal, perhaps there are not enough data in existence from which to form such an average. In the six anthracite tests by Johnson in Mr. Buel's Table XII., the amount of air supplied ranges from 18.4 to 47.9 lbs., the average being 26 lbs. In the comparative test between Babcock & Wilcox and return tubular boilers. published in Van Nostrand's Magazine in 1883, Mr. Hoadley found the weight of flue gases per pound of combustible to be respectively 30.71 and 32.10 lbs. Until direct experiment and analysis prove the contrary there seems to be no reason to suppose that the average amount of air supplied in burning a pound of anthracite coal is less than 25 lbs.

Let us suppose that the smallest quantity of air which will burn the carbon of the coal completely is supplied, viz., 12 lbs., or that the flue gases weigh 13 lbs. per lb. of combustible, and that the maximum probable calorific value of the combustible portion of anthracite is 14,544 heat units, and apply these two assumptions to experiments Nos. 5 and 9, Table XXV and No. 1, Table XXII of Mr. Buel's paper.

The results shown in this table lead to the conclusion either that the heating value of anthracite coal is greater than 14,544 heat units per lb. of combustible, or that the results of tests showing evaporations of 14.86, 13.32, and 13.31 lbs. are erroneous, the errors being due to neglect of determination of priming, or to possible inaccuracy of measurement.

That the first of these conclusions is untenable has already been shown, that the second is not unwarranted may be shown, not only by the necessity which follows from the exclusion of the first, but by an entirely independent line of argument.

I have selected from Mr. Buel's tables

- 1				
١		Vertica	al Wa.	
Į				Ctcod
١			ube	Stead
1		Boi		
١		(Isher	wood)	Boiler
-1		Table		
١		Laine.	2222 4 .	Table
١				Table
1		1		
1		No 5	No. 9.	XXII.
		10. 0.	140. 9.	
١.				
	1 TDb amount and the man lb			
1	1. Thermal units per lb.			
	combustible	14,544	14,544	14,544
٠ ا	2. Weight of flue gases			
	per lb. combustible	.13	13	13
		.10	10	10
1	3. Specifie heat of flue	1		
	gases	.238	.238	.238
٠	4. Temperature of flue			
		322°	600°	621°
	gases	522	000	0.21
,	5. Temperature of fire-			
١	room, say	91	68	68
	6. Thermal units lost in			
5		m1 -	1010	17711
	flue gases	715	1646	1711
•	7. Loss by radiation, prob-			
٠	ably not less than 4 per			
		582	582	582
,	cent. of 14,544		002	002
l	8. Thermal units available			,
f	for evaporation	13.247	12,316	12,251
L	9. Assuming above data:		1 '	1
9				
1	Maximum possible evap			
I	oration from and at 212°			
9	per lb. combustiblelb.	13.71	12.75	12.68
	10. Result of test	14.86		
)	11 11		10.0	10.01
r	11. Maximum possible effi-			
	ciency per cent		84.7	84.2
Э	12. Apparent efficiency ob-			
	tained in test		88.4	88.4
	tained in test		00.±	00.1
-	13. Apparent efficiency			
f	greater than maximum	1		
	possible per cent		4.5	6.0
2			1.0	0.0
	14. If we assume that the			
ľ	flue gases weigh 25 lbs		1	
1	per lb. of eombustible			1
•	maximum possible evap			
-			11 10	11 0=
t	oration would be		11.18	3 11.05
	15. Apparent efficiency	7		
\mathbf{S}	greater than maximum			
7			19.1	20.5
	possible per eent	. 15.2	18.1	20.0
S			I	
~				

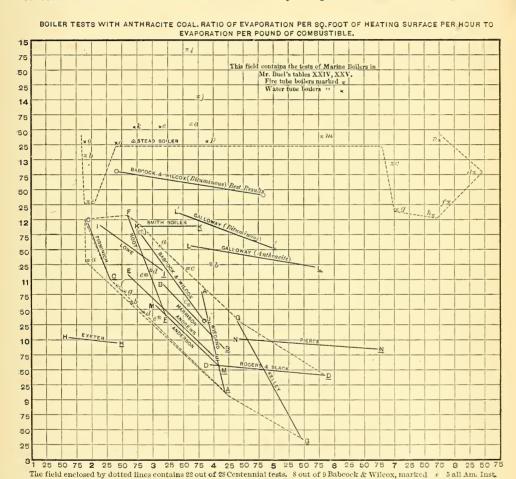
all the figures showing rate of evaporation from and at 212° per square foot of heating surface and per pound of combustible, and arranged them in the table beneath. Column II. contains, in addition to the tests given by Mr. Buel, a few (Nos. 10 to 13) obtained from other sources, and column III. contains some figures from the results of tests at the American Institute Fair, for comparison. I have plotted these figures on cross-section paper, using the lbs. per square foot of heating surface as abscissas, and the lbs. water per lb. of combustible as ordinates, and find that a large majority of all the tests are contained within a somewhat limited field, while a few, including

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	VIII.—Fire Tube and Water Tube Boilers. Table XXVI. Water evaporated from and at 212°.	-moo bustible.	13.55		13.71	9.08		8.24 8.14	6 4	
1	III.—Fire Tuland Water Tube Boilers. Table XXVI.	Surface. Per lb.								
	nd hibe	Builsed	2.71		3.43	6.13		2 10.01 4 11 80	16.08	
	VIII Try Wate	Number Pr. sq.ft.	က		_	70		65 4	6 1	
	VII.—Vertical Water Tube Boller. Table XXV. Water evaporated from and at 312°.	E. Pr. sq. ft. ∴ heating S surface. 14. Per lb. com- com- g.bustible.	75 14.06; .71 13.55% .13 18.557 79 13.39	7.75 13.32n $1.88 13.31o$ $3.89 13.30p$ $4.0 13.80p$						
i	VIII WWate	The Sq.ft.		00-1-0						
IANOIS.	VI.—Horizontal Fire Tube Marine Boiler. Table XXIV. Water evaporated V from and at 312°. f	heating surface. Per lb. com- bustible.	13.60a	13.08 <i>b</i> 12.92 <i>c</i> 12.77 <i>d</i> 12.29 <i>e</i>	12 28 <i>f</i> 12.17 <i>g</i> 12.05 <i>l</i>	-				
FORE	I.—I Fir Marin Tabl ater om a	Pr. sq. ft.	3.63	- œ -						
T IFW		Zumber	ಣ	<u> </u>	400					
OMIOAL	V.—Water Tube, Fire Tube and Cylinder Boilers. Table XXII. Water evaporated from and at 312°.	Per lb. com- bustible.	13 31 13 29		11 67 11.59		10.71	9.6 9.13	8 64	
NOOT C	.—Water Tub Fire Tube and ylinder Bollers Table XXII. fater evaporate form and at 313	Pr. sq.ft. heating surface.	2.69 1.8	3.31	3.61 3.86		2.95	$\frac{3.76}{4.55}$	7.51	
INV.		лэдшпХ			∞ es		9 .	-3 ↔	70	
COMPARATIVE INTES OF EVAPORATION AND ECONOMICAL LERFORMANDE.	IV.—Tests of Cylindrical Tubular Boilers. Table XXIII. Water evaporated from and at 312°.	E Per lb.				10.68 10.57 10.52		9.60	9.21	
F LVAIT	IV.—Tests of Cylindrical Cylindrical Tubular Boilers. Table XXIII. Vater evaporated from and at 212°	.fr. sq.ft. ∴ heating Serrace.				2.13 5.27 0.99		1.84	$\frac{3.46}{1.94}$	
3		19dmuN ∞	_			45-		<u> </u>	0 70	<u>·</u>
E IVAL	un Insti 371. d from	Per lb. com- bustible.		11.34a		$\frac{10.64b}{10.60c}$	10.49d $10.40e$			
ATIV	III. s at American I tute Fair, 1871. er evaporated fr and at 212°.	heating surface.		3 6.		3.3	3.83 3.10			
IVAIN	In American	.fr. sq.ft.		rd 1						
00	Test	.эшвИ		Blancha	11.31c $11.14d$ $11.10e$	Root	Phleger. Lowe			
	II. Babeoek & Wileox Boilers. Water evaporated from and at 212°.	Ser lb.	5. 5. 5.	11.82 $11.58a$ $11.58a$	11.21c $11.14d$ $11.10e$	10.91f $10.81g$	10.33	-		9.05
	II. oek & W Boilers. r evapol			011 80 110 80	200 200 200 200 200 200 200 200 200 200	2.40 2.54	3.84			4.02
	abeo 1 ⁷ ater rom :	.fr.ps.rq.ft. gairtead 4.6								
		zenamber			. 0 8 4 6 - 0 8 4	1048-	0 % H = 4	(@ 10 to w		7 111
	al Test aporate l at 212		12.125 12.094 11.988 11.925 11.925	11.906 11.822 11.609	11.216 11.163 11.064	10.93 10.83 10.61 10.61	10.330 10.312 10.041 10.041 10 021	9.86	9.56 9.43 9.14	8.30
	I. Centennial Tests. Water evaporated from and at 312°.	,3 · CL					8.4.1.4.8 4.0.0.4.8 88.8			
1	Ç ≱‡	Boiler.	上五の五丁	五で立て	ロアクロ	MAME	HNHG C	五女英円	はロれば	5

all the tests of column VII., nearly all those of column VI., but only a few of the others, were outside of the field. Some of the tests lay so far out of the field as to indicate some abnormal condition or some error. As there is nothing in the construction of the boilers to explain the positions of these tests, they must be due to exceptional qualities of coal, or to errors

Tests. (The italic letters are the capacity tests.) There were fourteen boilers, erected especially for test and competition. The same coal was used in the tests, and the same experimenter made them. The boilers were new and in excellent condition. It is to be expected therefore that every effort was made to secure the highest possible results. As is the case in of test. In the tests in columns VI. and every competition between strong rivals,



Fair tests, marked Contennial economy test, marked A. B., &c. Centennial capacity test, marked A. B., &c.

tainly errors due to primage, and they are unreliable from the fact that no priming tests were made, if for nothing else.

The figures in the tables herewith are arranged so as to show in some measure the same facts which the plotted diagram shows more clearly.

VIII. (Isherwood's) there are almost cer- in good condition for a race, several of the boilers came so close together in the front rank that it is difficult to distinguish between them. The five boilers at the top of the list which were tested with anthracite coal gave results ranging only between 12.094 and 11.822. These results are so close as to be within the limit Consider column I. the Centennial of accidental variation, and are certainly

within the limit of error of the calorimeter tests, which have been considered erroneous by many good authorities. Rejecting the test with bituminous coal, L', there follow five tests with results between 11 and 11.6 lbs., 8 between 10 and 11 lbs., and 8 between 9 and 10 lbs. With but few exceptions the tendency of the figures is towards decrease of economy with increase of rate of evaporation per square foot of heating surface. we leave out the Galloway test L, the five highest boilers show an average rate of evaporation of 2.66 lbs. per square foot 15.0 lbs., and 15×965.7=14,485 thermal of heating surface, the next four 2.93 lbs., the next eight 3.43, and the last eight 4.41 lbs., which figures would indicate that the heating value of anthracite is 17,320 if the rate of evaporation in the boilers which evaporated less than 11 lbs. of water per lb. combustible had been decreased, the economy of many of them might have been increased so as to bring them into the front rank.

The chief lesson to be learned from the Centennial tests, however, in this connection, is the fact that notwithstanding the great difference in construction of the boilers, the selection of the coal, and the generally favorable conditions of the tests, the highest result obtained by any of the boilers with anthracite coal is only 12.094 lbs. of water per lb. combustible. In a similar trial of five boilers at the American Institute Fair in 1871, column III., the best result is 11.34 lbs. best result yet published of the Babcock & Wilcox boilers is 11.822 lbs., or, rejecting the calorimeter tests as erroneous, 12.131 lbs. Surely these figures are sufficient to render it extremely probable that higher results than 12.131 lbs. per pound of combustible are not to be expected from such anthracite coal as was used in the Centennial tests, under similar conditions of pressure of steam and temperature of flue, and if any test shows a higher result, it is prima facie evidence either that the coal has a higher calorific power than the coal used in the Centennial tests, or else that the test is errone-The fact that the Babcock & Wilcox tests have been made with many different kinds of anthracite, and none of them have given better results than were shown in the Centennial tests is also an indication that there is no better anthracite in the market than that used at the Centennial.

Assuming what is probably true, that 80 per cent. of the total heating power of a coal can be obtained in a boiler working with high pressure steam and natural draft, and that the remaining 20 per cent. covers all losses from heat carried away in the gases of combustion, radiation, evaporation of moisture in coal, etc., and that this 80 per cent. was reached in the five Centennial tests showing the best result, say 12 lbs., then the heating power of the combustible portion of the coal is equal to an evaporation of $12 \div \frac{80}{100} =$ units.

If we assume, as Mr. Buel does, that thermal units, then the best result obtained at the Centennial would show an efficiency of only 67.5 instead of 80 per cent. It would be difficult to figure up a loss of efficiency in the best of these tests of 32.5 per cent. without assuming an enormous excess of air in the flue gases, an enormous amount of radiation, or else imperfect combustion. It is not conceivable that either of these conditions could be allowed in the five tests showing the best result, and we are forced to the conclusion therefore that the heating value of anthracite coal is not anything near 17,320 thermal units per lb. of combusti: ble, but is more nearly 14,500 thermal

But Mr. Buel may answer, all this is pure theory, and is opposed to the actual results obtained from the experiments of Isherwood on Marine boilers, and the experiments on the Stead boiler. rejoinder is, that the theory is based on a larger number of facts, and better attested than Isherwood's or Stead's, since in neither of these cases was there any competition between rival boiler makers, nor is there any evidence that such precautions were taken to insure accuracy as were taken in the tests at the American Institute Fair and at the Centennial. So convinced am I of the fact that the heating value of American anthracite is not materially greater than 14,500 thermal units per lb. of combustible, and that it is not possible to obtain more than a trifle over 12 lbs. of water evaporated from and at 212° per lb. of anthracite combustible in any high pressure boiler with natural draft, that if I should obtain a higher result in a test, I would discredit

my own figures, and make the test over again.

In column II. I have introduced some figures of tests of Babcock & Wilcox boilers in addition to those given by Mr. Buel. No. 10 is from a test by Mr. Geo. H. Barrus, using a mixture of anthracite screenings and Powelton semi-bitumin-It shows two facts, 1st, that the semi-bituminous coal has a greater heating power than anthracite; 2d, that although the boiler was driven at a very high rate of evaporation it still showed excellent economy, and indicates an error in Mr. Buel's statements that water-tube boilers are not economical at high rates of combustion.

Nos. 11 and 12 are two tests of the same boiler made by myself. No. 11 was with poor pea coal, and No. 12 with clean The higher rate of combustion shows the best result. No. 13 was a test made by my assistant with a semi-bitu-It confirms Mr. Barrus' minous coal. test, No. 10, in showing that the semi-bituminous coals have greater heating value per lb. of combustible than the anthracites.

Mr. Buel makes another thrust at sectional boilers in respect to their safety. Instead of taking an English experience as old as 1878, in which 79 per cent. of all the boilers are of patterns rarely used in this country, and only 15 per cent. are externally fired boilers, he might have taken present experience in this country, with probably 79 per cent. of externally fired boilers, which are continually exploding with great loss of life, and probably 15 per cent. of sectional boilers, none of the chiefly used and properly designed varieties of which have ever yet been known to explode, except in detail, doing no damage to life.

Considerable space is taken by Mr. Buel in proving that in a boiler with good furnace heating surface this surface evaporates the greater part of all the water that is made into steam by the boiler. In any boiler in which the furnace heating surface bears a large ratio to total heating surface this must follow as a necessary consequence of the law that the

does not nevertheless follow that it is best to design a boiler with large ratio of furnace to total heating surface. The writer has made experiments with Babcock & Wilcox boilers in which the furnace heating surface was materially reduced, by protecting it from radiation from the fire by means of a fire-brick arch. The results were as well as could be expected with the coal used (Penn'a. & Illinois bituminous), and very much better than he obtained with the same coal and the same boiler without the arch, or with the same coal and different boilers, in which the ratio of furnace to total heating surface was quite large.

Mr. Buel depends for a considerable portion of his argument upon the theoretical efficiencies derived from Rankine's form-To show how much dependence should be placed upon this formula it may be well to refer to Rankine, (Steam Engine and Prime Movers p. 293).

"Hence it may be expected that the efficiency of a furnace will be expressed to an approximate degree of accuracy by

the following formula $\frac{E}{E'} = \frac{SB}{S + AF}$

which A is a constant which is to be found empirically, and is probably proportional approximately to the square of the quantity of air supplied per lb. of "B is a fractional multiplier to allow for miscellaneous losses of heat, whose value is to be found by experiment." "The formula is of course not intended to supersede experiments and practical trials, nor to give results as accurately and satisfactorily as such experiments and trials, but to furnish a convenient means of estimating approximately the evaporative power of fuel in proposed boilers, and the comparative efficiency of different boilers. The formula is framed on the supposition, etc." Rankine's formula was first published in 1859.

In so far as his constants are based on experiment, they are on experiments with boilers of a class not often used in this country for stationary purposes, and with coals which are in every way dissimtransmission of heat varies approximately lilar from our anthracites. It is useless as the square of the difference of temper- therefore to predicate anything concernatures on the two sides of the plate. It ing the various types of boilers not known to Rankine in 1859, and fired with coal of a character not known to him, by means of his formula, based as it is on probabilities and suppositions, without first correcting the constants in it, as Rankine himself directed, by means of experiment.

Lest the length to which this article has grown may lead to some confusion in the mind of the reader as to the exact points of my disagreement with Mr. Buel I will restate briefly my positions as follows:

1st, There is no reason to believe that American anthracite coal has a higher heating value than 14,544 thermal units per lb. of combustible.

2d, It is probable that the average air supply to furnaces burning anthracite coal, when it is thoroughly burned, with natural draft, is not much less than 24 lbs. per pound of combustible.

3d, That any test of a boiler at high pressure, with American anthracite coal, and natural draft, which shows a result exceeding 12 pounds water per pound of combustible should be discredited, at least until competing tests by a board of experts, such as the American Institute Fair or the Centennial tests, shall have shown that a higher result can be reached in practice.

4th, That while heating surface in the furnace may transmit more heat to the water than surface which is beyond the furnace, it by no means follows that greater economy will be obtained by making the ratio of furnace to total heating surface greater than now prevails.

5th, That no sound argument can be based on Rankine's formula in relation to American anthracite practice, until the constants in it are corrected by experiments for the particular class of boiler and of fuel in question.

6th, That water-tube boilers do not give inferior results at high rates of combustion, if they are properly propor-

7th, That notwithstanding the letter of that a certain Insurance Co. had no ex- question.

plosions, disastrous explosions are very common in this country with ordinary shell boilers, while no serious explosion has been known of a boiler properly called sectional.

8th, That the test of the Stead boiler, No. 1, Table XXII., must be discredited, and it is not probable that the Stead boiler can be made to show any better results than 12 pounds of water per pound of combustible when run under high pressure and natural draft, and with coal similar to that used in the Centennial tests.

THE TENSITY AND PRESSURE OF DETONATING GAS MIXTURES.—MM. Berthelot and Vielle have recently been studying the influence of the density of detonating gaseous mixtures upon the pressure developed. The measure of pressure developed by the same gaseous system, taken under two initial states of different density to which the same quantity of heat is communicated, is an important matter in thermodynamics. If the pressures vary in the same ratio as the densities, we may conclude, independently of all special hypothesis on the laws of gases, first, that the specific heat of the system is independent of its density (that is to say, of its initial pressure), and depends only on the absolute temperature, whatever that may mean; and secondly, that the relative variation of the pressure at constant volume, produced by the introduction of a determinate quantity of heat, is also independent of the pressure and a function only of the tempera-Lastly, the pressure itself will vary proportionally with the absolute temperature, as defined by the theory of a perfect gas, and will serve to determine it. MM. Berthelot and Vielle operated with a bomb, at first kept at ordinary temperatures in the air, and afterwards heated in an oil bath to 153 deg. Cent. They also employed isomeric mixtures of the gases, methylic ether, cyanogen, hydrogen, acetylene, and other gases were experimented upon, and the general conclusions are as follows: 1. The same quantity of heat being furnished to a gaseous system the pressure of the system varies proportionally to the density of the system. 2. The specific heat of the gas is sensibly independent of the density as well towards very high temperatures as about 0 deg. Cent. This is all true for densities near to those that the gas possesses cold under normal pressure, and which varied in the experiment to double the original value.

3. The pressure tioned for such high rates, to any greater extent than any other class of boiler.

increases with the quantity of heat furnished to the same system. 4. The apparent specific heat increases parallel with this quantity of heat. These conclusions are independent of all hypotheses on the nature and laws of gases, and an English authority in 1878 which shows were simply drawn from the experiments in

EXPERIMENTS WITH COMPRESSED GUN COTTON,

CONDUCTED IN THE MANUFACTORY OF MAX WOLFF & CO., WALSRODE.

BY THE SUPERINTENDENT, MAX VON FORSTER, Engineer, Premier-Lieutenant a. D.

Translated from the German, with consent of the Author, by Lieut. JOHN P. WISSER, U. S. Army.

The following experiments have for an object to determine in what manner compressed gun-cotton should be applied to obtain the greatest and most useful effects. Many experiments have already been made with this object; it is difficult to arrive at correct results since we have no accurate instrument for measuring the force of quick-burning explosives.

Nevertheless, the author believes that, assisted by his long-continued practice in military and civil work with explosives, he has been able, supported by the following experiments, to arrive at an approximately correct conclusion on the effects of the various kinds of explosives.

The differences in effect between the less rapid-burning and the more rapid-burning, between the rapid-burning and the slow-burning, are so marked that they may be easily observed, and compel the admission that certain conclusions may be drawn therefrom.

Moreover, as superintendent of a guncotton factory, the author has the opportunity, and it is in fact his duty, to work with this explosive; material, time and place are always at his disposal for these investigations, so that he may hope to have made some progress in the preparation of gun-cotton, as well as a few observations on its properties. The author will, nevertheless, be very grateful for every correction, and also for any contributions on other experiments in the same field, and will gladly modify his views through other obtained results, continuing, meanwhile, his own researches.

The gun-cotton used is, unless otherwise stated, such as is prepared in Germany and other states for military purposes, and is made in the factory of Messrs. Wolff & Co., Walsrode. It contains 12.3 per cent. nitrogen in the ashfree substance, and is in the form of cylinders 30 mm. in diameter and 70 mm. or more in height, and has a specific gravity of one; a few pieces of larger

The following experiments have for an diameter, having a specific gravity of 1.1 eject to determine in what manner com-

By dry gun-cotton is understood that which has been dried until its weight is constant, and has then absorbed about 1 per cent. of moisture from the atmos-

phere.

Wet gun-cotton has absorbed in 100 parts of gun-cotton by weight the parts of water given, mostly 25 per cent. For the detonation of dry gun-cotton primers (called detonators) are used, containing 1 grm. mercury fulminate, which are fired partly by electricity, partly by means of Bickfords' quick-match.

The object to be exploded consists of a leaden cylinder 46 mm. in diameter, set upon a small iron plate lying on the solid ground. The cartridges are placed on

the leaden cylinder.

It is to be remarked that the cartridges have a greater effect on the shorter than on the longer leaden cylinders, that therefore only those explosions, which occurred on cylinders of the same height, can be directly compared.

The annexed drawings exhibit the leaden cylinders in cross-section and plan,

after the explosion.

Following the experiments on the effects of explosion are given certain observations on, and other experiments with, compressed gun-cotton.

EXPERIMENTS ON THE EFFECTS OF EXPLOSION.

In Plate 1 the explosions Nos. II., III. and IV. were made with cartridges of 50 grm. gun-cotton 70 mm. long; Nos. I. and V. with cartridges of greater weight, but also of greater length; the increased weight had no increased effect, on the contrary, the effect in case of the longer cartridges was diminished.

cylinders 30 mm. in diameter and 70 mm. The explosions VII., VIII. and IX. or more in height, and has a specific were produced by cartridges of the same gravity of one; a few pieces of larger size as II., III. and IV., not solid, how-

ever, but hollow, as shown in Plate 1, Figure 2.

The effect on the leaden cylinder is greater in case of the hollow cartridges although the solid ones were greater in

weight.

The explosions VI. and X. are analogous to I. and V., with cartridges of greater weight, but also greater length, than VII., VIII. and IX. The effect of both is again less than of those conducted

with less weight.

It follows therefore, that in case of dry gun-cotton no increased effect is produced by increasing the charge, if at the same time the length of the charge is increased; furthermore, it appears that in a long cartridge of dry gun-cotton the upper parts cannot transmit their detonation to the lower parts in the same explosive shock as that effected by the initial detonation of the primer, and hence it follows that in long charges of dry gun-cotton it is better to use several primers, placed some distance apart, and to fire them by electricity, in order to produce the greatest possible effect of the total charge.

These relations are more apparent in case of gun-cotton mixed with saltpeter

and of wet gun-cotton.

In Plate 2, IX. is a cartridge of guncotton intimately mixed with 50 per cent. barium nitrate ("Baryt saltpeter"), constituting an almost homogeneous mass. The cartridge is 70 mm. high, weighing 65 g.; the explosion VIII. is of a similar cartridge, but 220 mm high and weighs 225 g.; now, although the effect of the latter cartridge is not increased in proportion to the increased weight, it is never- Dingler's Journal, 1874: theless greater on the whole, and indeed cartridge, while in the case of dry guncotton the effect was diminished.

Explosion X. consists of two wet cartridges with 25 per cent. water, and a dry one of 50 g. for the production of the

detonation.

Explosion XI. consists of three wet

and one dry cartridges.

The effect of these two explosions is the greatest of those thus far described; it is considerably greater than that of the dry priming cartridge alone, and much greater than that of the long charges of dry gun-cotton. In case of the wet guncotton the detonation was propagated

throughout the entire length of the charge. Moreover, the wet gun-cotton is, on the whole, more sudden in its effects than the dry.

The dry gun-cotton depresses the center of the leaden cylinder and bends the edges over, but both parts have, nevertheless, a smooth surface; in case of the wet gun-cotton the part of the lead referred to was torn and pulverized.

Similar effects have been obtained with the very sudden explosives prepared from nitric acid and binitro benzole, as well as from nitrous acid and sulpho-

carbides.

Professor Abel, in his highly important experiments, described in Dingler's Polytechnisches Journal, 1874, has shown that the rapidity of propagation of the detonation of dry gun-cotton is considerably less than of wet gun-cotton; the above experiments show that this is also true with respect to the effects of the two kinds of gun-cotton; furthermore, that in a long charge the effect itself of the dry gun-cotton diminishes towards the end of the charge, while that of wet guncotton does not.

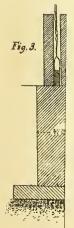
Professor Abel found, further, that in long charges of gun-cotton the rate of propagation of the detonation was uniform, being as great in the last meter as in the first. But he used gun-cotton with 30 per cent. water; for, otherwise would have been the results had dry guncotton been used. This will probably have a slower rate of detonation towards the end of the charge.

Professor Abel says, moreover, p. 318,

"The more energetic action produced considerably greater than in the former when gun-cotton and its preparations are detonated in a moist condition, has furnished the striking proof that the detonation is transmitted the more easily, and the transformation of solid to gas and vapor takes place the more suddenly the less the compressibility of a given explosive mass subjected to the action of a sufficient initial detonation. Since the water replaces the air contained in the compressed masses, the propagation of the detonation will evidently be favored by the increased resistance which the particles offer during the instant of detonation."

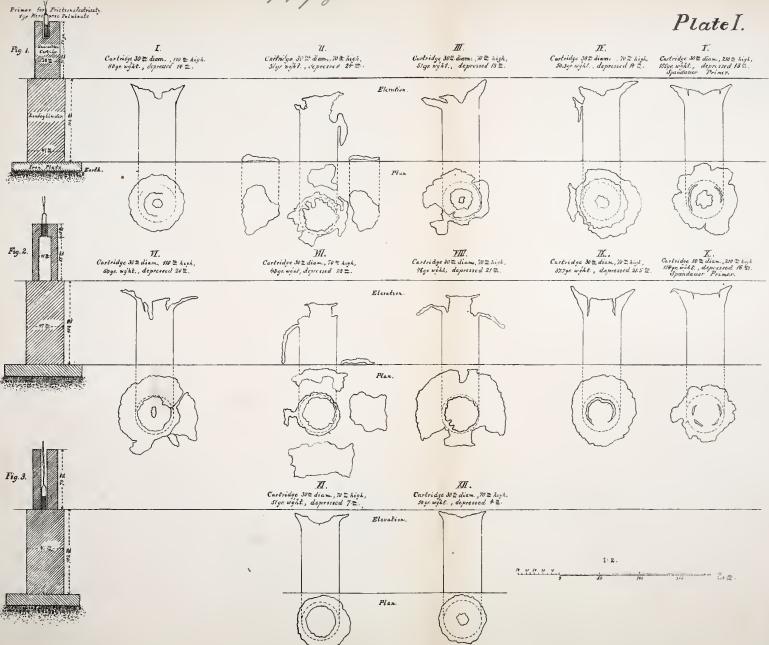
True as these propositions are they with at least equally great suddenness do not explain the difference in action re-







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ferred to between dry gun-cotton and wet gun-cotton containing 30 per cent. of water. The latter is more easily compressible and less compact than dry, and is much more easily subject to being crumbled and torn up than the dry. When it is desired to work over dry pieces of gun-cotton in the factory, which indentation present in the piece of gunmust therefore be first crumbled, they are moistened, because they are then more easily crumbled. The particles of a wet smaller resistance to the initial detonation against tearing and dispersion than those of a dry cartridge.

The initial detonation acts principally by the shock; when this strikes a dry cartridge filled with air the air acts to diminish the shock; because it is elastic it is compressed and transmits a slighter shock than it received. The water in a wet cartridge is not compressible; it transmits the received shock with a force

equal to that which it received.

The explosions Plate 2, I., II. and III., exhibit a clear view of the necessity of giving the charge and the object to be destroyed the largest possible surface of contact, and the charge itself the least

possible height.

No. I. is 18 mm. high, No. II. only 13 mm., but has a larger surface of contact with the leaden cylinder; the latter has produced a greater effect than I. in spite of its less weight; explosion III., with triple the weight, but also triple the weight of charge of II., has accomplished but little more than the latter.

The same effect of the form of the charge is shown in Plate 2, explosions IV. and V., and also VI. and VII.

Explosion VI. has a flat charge, lying close to the object, and has acted with considerably more force than VII., in which the same weight of gun-cotton is applied in a high and narrow form.

In all these results it is remarkable that the difference of effect is already apparent with small differences in dimension; a charge 13 mm. high acts more energetically than one 18 mm. high, and a still greater difference is found in the 68 mm. high of equal weight.

If we place a piece of compressed guncotton on a piece of iron, an accurate of the mercuric fulminate? impression of the form of the under surface of the gun-cotton is produced by the original direction of the gases is main-

detonation; the gases acting on the iron have occupied exactly the same space, and no more, that the solid explosive previously occupied. As long as the detonation gases act they have not yet expanded on the whole.

Every angle, every depression, every cotton, is copied by the gases and impressed on the underlying iron, and we may also conclude herefrom that only the cartridge will probably offer a much gases evolved by the very undermost layer of gun-cotton act on the iron, while the others are lost.

If we observe the action of compressed gun-cotton, as compared with that of dynamite, on compact rock, with the application of drill holes, it will be found that gun-cotton destroys the interior of the drill hole, that it completely pulverizes the rock, but that it does not eject the pieces as dynamite does. The action of gun-cotton seems to be more sudden, but more local, than that of dynamite.

If we could give the gases of the detonated gun-cotton a fixed direction towards the object the effect would be increased. The experiments here given furnish two means of attaining this end

to a certain degree.

In Plate 1 the primers are set in the cartridge on the side opposite the object to be destroyed in all the explosions, except XI. and XII., in which the primer is placed in that part of the cartridge which is in contact with the object. The effect of these last two explosions is much less than that of the others.

The detonation of the primer gives the detonation gases a direction away from itself, a direction towards the side oppo-

This fact may be explained by the transfer of the vibrations of the gases of the primer to those of the gun-cotton, when the gases of the primer have a fixed Simpler is the explanation direction. that the detonation gases of the primer form, to a certain extent, a dam, so that they offer from the beginning a resistance to the gases generated from the gun-cotton, and thus press them toward the action of one 30 mm. high, and another other side. Even a very weak dam of loose earth acts on the gases of the explosive, why not the energetic detonation

At what point in the cartridge the

tained has not yet been determined; according to the experiments here given, the distance does not seem to be very great, but the direction given by the initial detonation, in case of a cartridge of a weight of over double the diameter, 70:30, becomes quite noticeable. In explosions in a closed space the same phenomena occur, as illustrated in Plate 2, explosion XV.

The cartridge is here enclosed in a block of lead, and the opening, through which the cartridge was introduced, is closed by a leaden stopper. The latter is fastened with iron bands. The cartridge is therefore enclosed equally firmly on all sides. The primer is not introduced into the cartridge but is simply in contact with it.

In this explosion, a circumstance unfavorable for this phenomenon was that complete, since the iron bands, which held the leaden stopper, were fractured by the explosion, so that the stopper was carried away, and gases were enabled to escape prematurely on the side of the primer. Otherwise the action would have been even more energetic than it actually

The primer must therefore always be placed on the side opposite the charge.

The second method of giving the detonation gases a fixed direction, consists, according to the experiments, in furnishing the cartridge with a hollow opening, on the side opposite the primer and adjacent to the object to be destroyed. Explosions VI.-X., Plate 1, furnished with hollow cartridges are, on an average, considerably more violent than I.-V., although the latter were of the same size, but greater in weight, since they were solid.

An increased action, in case of the hollow cartridges, takes place exactly in the direction of, and over the entire crosssection of the opening. More clearly is this shown when, in place of lead, the more brittle metal, iron, is taken as the object to be destroyed.

In explosions XII.—XIV., Plate 2, wrought iron was selected as the object. In XIII. and XIV. a strong impression of the cross-section of the hollow opening of the cartridge appears, which is twice the depth of the impression produced by a solid cartridge as in No. XII.

On the whole, the effect of hollow cartridges is greater than of solid cartridges of equal size though greater in weight.

In explosions where the space, in which the exp'osive charge is placed, is limited, as in the explosive charges of shells, in which the explosive charge and the object to be exploded cannot receive a larger surface of contact than that of the interior of the shell, it is best to apply both means described, viz.: the hollowing of the charge and the placing of the primer at the base of the shell, in order to obtain an increased action towards the head of the shell, in which direction also the object to be destroyed will almost always

The use of wet gun-cotton instead of dry will also offer extraordinary advantages.

In the application of gun-cotton it the enclosing of the cartridge was not must be added that, aside from the fact that the action of the explosive charge is greater, the wet gun-cotton, as is well known, is much less dangerous in the preservation and handling thereof than the certainly very slightly dangerous dry. The combustion of a large supply of guncotton, and hence a loss thereof by fire, will be prevented by wet storage of it.

COATING OF GUN-COTTON BY MEANS OF A SOLVENT THEREOF.

Compressed wet gun-cotton has many inherent disadvantages: the water evaporates readily, and the cotton must therefore be moistened again from time to time (although this may be greatly diminished by good packing and storing in magazines), moreover wet gun-cotton crumbles easily, and even very well packed wet gun-cotton may suffer much in long-continued transportation, finally it is subject to the formation of fungus, which will in time destroy its structure. It may be remarked, in passing, that the formation of fungus is favored by the presence of paper in the packages, which shall therefore be carefully avoided.

The author has, however, discovered a process for avoiding or largely diminishing the above-mentioned objections to wet gun-cotton. It is as follows:

If we dip pieces of wet gun-cotton for a short time, $\frac{1}{4} - \frac{1}{3}$ minute, into good acetic ether, into nitro-benzole, or into other solvents of gun-cotton, then take them out and allow the solvent to evaporate,

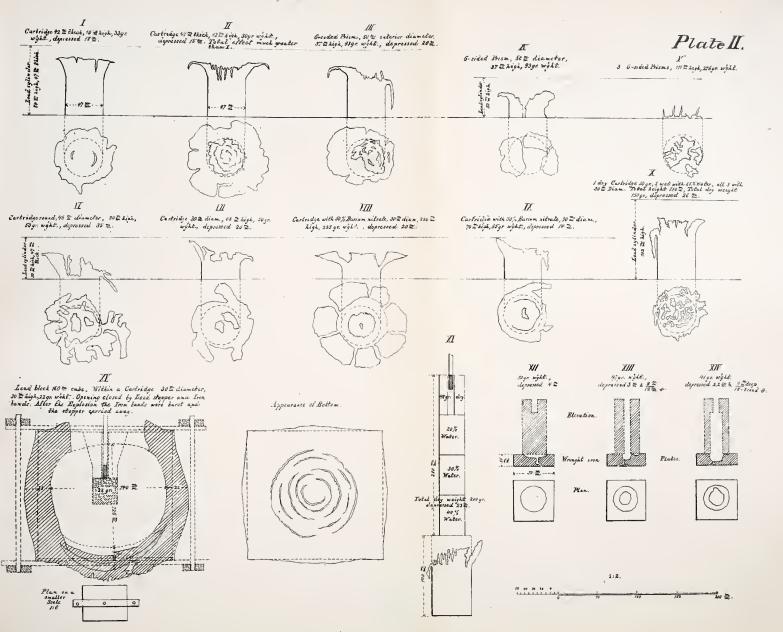
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cotton a very thin, but very compact coating, which gives it a very firm shape, protects it against crumbling and pre-

vents fungoid growth.

This coating, which consists of dissolved gun-cotton, and which should be absolutely water-tight, nevertheless does not protect completely against the gradual drying of wet gun-cotton; there are formed in the coating very fine, invisible cracks, through which the water, though

slowly, evaporates.

A piece of gun-cotton not thus coated, containing 25 per cent. water, will become air-dry (i.e., with 2 per cent. moisture) in summer in a current of air, in several days, whereas in case of gun-cotton coated by means of ether, etc., several weeks will be required. The dried piece placed in water takes it up again. But this does not proceed very rapidly; in case we wish to effect the absorption of moisture quickly, in $1-1\frac{1}{2}$ hours, we can, in the process of manufacture, leave little uncoated spaces in the coating, through which the water may penetrate rapidly.

The process described can also be applied with advantage to dry gun-cotton.

If we coat a piece of dry gun-cotton, supplied with an opening for the reception of the primer, by means of a solvent, the gun-cotton will first, as in the case of wet gun-cotton, receive a firm, permanent form, and secondly, the cartridge, as well as the opening for the primer, will be protected against moisture, without interfering with the introduction of the primer, as would be the case were the opening specially closed by a sheet of paper, and also without diminishing the capacity to explode, as would be the case were the opening lined with copper, etc. The thin coating of gun-cotton offers no resistance to the action of the primer; many experiments have proven that such cartridges will detonate with a ½-grm. primer. Moreover, such a cartridge can be used under water directly, without the necessity of introducing the primer watertight.

It is possible to prepare pieces of guncotton, by means of such a coating, so water-tight that when placed in water for several weeks they will not increase in weight; however, this does not always seem to be formed.

there will be formed on the piece of gun- therefore more recently coated only the walls of the opening for the reception of the primer by means of ether, and rendered the other portions impermeable by dipping them in melted paraffin. By this. means water-tight cartridges have been

uniformly obtained.

The opening for the primer may also be made water-tight, by lining it with copper, etc., but there follows a great objection in that the capacity to explode readily suffers, since, first, a layer of air forms between the gun-cotton and the lining, secondly, the lining must be broken by the primer, and thirdly, another layer of air, or, in case of explosion under water, a layer of water, exists between primer and lining.

It happened often to the author that, in explosions under water, when the priming cartridge was adjusted by a copper lining, in spite of the use of the best primers, the gun-cotton charge began toburn indeed, or to decompose into dense red fumes, nitrous acid fumes, etc., but

did not detonate.

This decomposition of gun-cotton into nitrous acid fumes, etc., caused by an insufficiently energetic initial detonation of the primer, appears not to have been elsewhere noticed.

In the manufacture of gun-cotton, during the nitration of the cotton, this decomposition is of common occurrence when the temperature rises too high.

The process of rendering the opening for the primer impermeable through ether coating may furthermore be of importance when wet gun-cotton must remain in close contact for a considerable time with the dry priming-cartridge, since, in case it is not made impermeable, it is to be feared that the evaporation from the wet gun-cotton will moisten the dry. This takes place very easily and rapidly, and can hardly be avoided in case one may wish to use both wet and dry gun cotton as in shells.

The principal advantage of the process described is that it gives the wet gun-cotton a permanent form, and thus renders

it applicable in war.

SPONTANEOUS DECOMPOSITION OF GUN-COTTON.

The author is in possession of a piece succeed as in this case also small cracks of compressed gun-cotton of the year The author has 1878, which, in the process of manufacsmells sour, burns when ignited with a missed fire may occur. white flame (gun-cotton with a red flame) and emits no appreciable vapors. In an in the laying of sub-marine mines, which air-tight preserving-jar, in which a part need be operative but for a limited time, of this experimental prism of gun-cotton was preserved, no pressure has been noticeable since the decomposition has set

This phenomenon shows that the spontaneous decomposition of poor gun-cotton takes place without the production of flame, and the author believes that a spontaneous combustion of gun-cotton has never occurred. Of course, gun-cotton subjected to high temperatures, such as can only be brought about artificially, temperatures above 120° C., is not here included. Good gun-cotton is sufficiently stable for all practical purposes.

How many unforeseen accidents may cause combustion is proven by the following experiment, communicated to the author by Professor Kraut, in Hanover.

If we take a good handful of simple cotton wadding, set a portion of it on fire and wrap the other part around the kindled point, so that the air is excluded, the piece of wadding may be wrapped in paper and preserved for months.

If, at the end of this time, the wadding is unwrapped and air admitted, the part kindled months before goes on burning and consumes also the rest of the cotton.

How often may this phenomenon have of ordinary cotton in large bulk, it was said to be due to spontaneous combustion. With gun-cotton it was probably often the same.

AN EXPLOSION UNDER WATER.

It would be of great interest if a charge of gun-cotton, which has been placed under water, could be preserved explosive for a fixed time, and be so arranged that, after another fixed time, it will cease to be explosive, and thus render itself inex-

ture, was not completely washed, so that in harbors, etc., because in these cases some acid remained. The piece was preships and workmen in diving-bells and served during this time in a chest kept diving-clothes must approach the point in a dry place. It is now completely of explosion in order to undertake the decomposed, and has become a greenish, work of clearing away, and to accomplish soft mass, which has lost the structure this work pounding and striking with and appearance of gun-cotton, and, when heavy iron tools is necessary, by which pressed, yields a glutinous liquid. It after-explosions of charges which had

> It may furthermore be of importance and must not be dangerous to our own shipping thereafter, and must moreover be capable of being raised without dan-

The author hereof has discovered a method of procedure which meets these

requirements.

When a cylinder of compressed guncotton is so enveloped that only the bottom, that is, the part opposite the primer, is not water-tight, and is set in water, the latter will gradually penetrate into the cartridge from the bottom upward and thus wet it. When the water has nearly reached the primer, and an amount of dry gun-cotton is therefore present, not sufficient, even if it detonates, to cause the detonation also of the wet gun-cotton, the charge or mine is no longer capable of detonating, and becomes perfectly

In a short while the rest of the dry gun-cotton becomes wet and the priming will be entirely useless.

Therefore, in explosions with gun-cotton under water a priming-cartridge, as above described, is used, the rest of the charge being composed of wet gun-cot-

The priming-cartridge is easily enclosed occurred when, in case of a combustion so that only the bottom thereof is permeable to water by enveloping it in a rubber tube open below, in the upper part of which the priming is tied water-tight. The cartridge may also be made impermeable by means of paraffin or a coating of ether, and the bottom then cut off. The coating with ether has the great advantage that the opening for the primer is made impermeable at the same time. The coating produced by ether is sufficient also in itself, without the rubber tube.

In the case of sub-marine mines many This would be of importance in all other absolutely safe means naturally blastings of rocks in the beds of rivers, offer themselves for the preparation of

the priming-cartridge, according to the same system and for the purpose in view.

A cartridge of pure gun-cotton, of specific gravity 1.1, 100 mm. high, remains explosive for about 8 hours, and in 11 hours is completely wet and entirely incapable of being exploded by shock. A cartridge of gun-cotton mixed with saltpeter remains dry longer than one of pure gun-cotton.

The specific gravity, the length of the cartridge, and the extent of surface through which the water can penetrate, constitute factors sufficient to determine satisfactorily, within certain limits, the time during which the charge will remain explosive, since, with proper care, cartridges may be furnished sufficiently uniform in character to produce a uniform action.

ELECTRICAL CONDUCTORS.

BY WILLIAM HENRY PREECE, F.R.S., M. Inst. C.E. Proceedings of the Institution of Civil Engineers.

DISCUSSION.

Mr. Brunlees, President, said he thought the discussion might well be taken in three parts. First, as to the qualities which electrical conductors should possess; next, as to the manufacture of the conductors, and then, having the electrical conductor according to the conditions laid down by men of science, and according to the possibilities of manufacture, on the practical use of the conductor. He would first ask Mr. Preece if he desired to add anything before the discussion commenced.

Mr. Preece expressed his deep regret that one seat at the Council table was empty, a seat that had been filled by one who had taken a prominent part in the discussion of every electrical paper brought before the institution. The late Sir William Siemens had taken the deepest interest in the subject, and had succeeded very largely in enriching it. Mr. Preece had brought forward many facts to illustrate the improvement effected in

metals and showing how they were produced. In speaking of them in his paper he had been compelled frequently to use a term which was familiar in the mouth of every electrician as a household word, but which had not yet become familiar to engineers—the term "resistance." He had spoken throughout the paper of the resistance of wires, knowing well, as an electrician, what the term resistance meant; but many engineers assumed that it meant mechanical resistance—resistance to tension or to rupture. It was a misfortune that the term had been too freely introduced, and it would have been better if he had spoken entirely in terms of conductivity. If he had said that a copper wire conducted electricity six times better than iron wire of the same dimensions, he should have been better understood than by saying that a piece of wire had one-sixth of the resistance, or six times the resistance, as the case might be. Sir William Thomson had pointed out in that room how it was that conducelectrical conductors during the last tivity was the exact reverse or reciprocal quarter of a century, and he hoped that of resistance, and he went so far as to the discussion would elicit other facts, suggest that there ought to be a stand-showing how the mechanical and elec- ard for conductivity, as there was a trical qualities of the various metals had standard for resistance. That point had been almost metamorphosed. The chief not, however, yet been reached. But, point that he desired to emphasize was should he still use the term "resistance," the position that copper was likely to be wished it to be clearly understood that take in the future, and the remarkable he meant by it the reciprocal of conducmechanical powers that it evinced. He tivity. Resistance was expressed in had brought for inspection a number of terms of a standard called the ohm, specimens illustrating the behavior of and he believed the day was not far distant when every one would know but it was better to do it independently. what an ohm was as well as what a The second machine exhibited, clamped, foot was, or what a meter was. length, a column of mercury, about 1 meter in length, of 1 square millimeter section. But in dealing with copper and test was the torsion test—a test for torwith iron, a standard had been introduced expressed in weight per mile. Copper wire weighing 842 lbs. per mile gave an ohm, and was called a mile ohm of copper; iron wire weighing 4,500 lbs. gave a mile ohm of iron; so that the ries of spirals was formed, and the numrelative dimensions of that curious standweight. He had brought for exhibition the test upon iron, and, if time permitted, upon copper, for he wished the on the square inch, while the iron used for telegraphic purposes possessed a breaking strain of only 22 tons. Again, there was an impression that copper was considerably; but he had figures showiron; indeed, the copper wire then used stretched considerably less than present day was better than the iron. The machine exhibited was that used for As at present arranged, the machine would register from 1 lb. to 5,000 lbs. There was a length of wire applied which was clamped in such a way that there of the wheel and the multiplying gear, a slow motion was brought to bear, a weight was gradually applied to the wire until it broke. The piece of wire tested weighed 400 lbs. to the mile, and it was The wire, it would be seen,

The a length of ten inches. (The wire was ohm standard was expressed by a certain here tested for stretch.) The wire, it would be seen, had given way after stretching 15 to 16 per cent. Another sive capacity. It was not desired that the wire should resist torsion, but should bear torsion. By making an ink mark along the top, and by twisting the wire in the other machine until it broke, a seber of the spirals indicated the torsive ard depended both upon length and capacity. All wires were specified to show a certain number of twists. the various instruments that were used wire experimented upon was taken from to test the metals, and he would show a coil of No. $7\frac{1}{2}$, and all the pieces had been cut off the same length. He would next experiment upon copper wire No. 14. members to have distinct evidence of the Meanwhile he would refer to the enorremarkable mechanical qualities of the mous advantage which copper wire would copper produced at the present day. give for overhead purposes. There was The copper wire specimens on the table then going on what he had characterized possessed a breaking strain of 30 tons as a meaningless crusade against overhead wires. Vestries and other small corporations in outlying districts were endeavoring to force the Government to put the wires underground, and the newsvery plastic, and that it stretched very papers were bringing forward the fact that even in Germany and France the ing that it did not stretch so much as wires were so placed. It was not sufficiently known that Germany and France were only doing what had been done in iron; so that in both properties, tensile England a quarter of a century ago. The strength and elasticity, the copper of the wires were then placed underground; all the main wires in the country between London, Birmingham, Liverpool, testing the breaking strain. There was Manchester, Leeds, and all the wires to a system of levers and a shifting weight, the cables on the south coast, were underground; but after sufficient experience of their use it was found necessary to take them up again; and he should not be in the least degree surprised to find was no nipping or biting, and it suffered the same result taking place, sooner or no mechanical injury. When, by means later, in Germany and France. It had been found that wires overhead had many times the efficiency of wires underground, and it was absurd to try and force electricians to do an act that was commercially wrong and practically foolknown as $7\frac{1}{2}$ by the centimeter gauge. ish, for the imaginary reason that over-(The wire was then tested for tensile head wires were supposed to be dangerous. Statistics showed that in the United had broken at 1,160 lbs., the specified Kingdom there were 18,000 persons breaking strain being 1,080. It was also killed by accident every year. The avernecessary to record the stretch, which age for the last thirty years-during the was sometimes done at the same time; period of telegraphs—was about 12,000

per annum. In that period about 400,-000 persons had been killed by accident, and of that number two only had been killed by telegraph wires. One of those accidents was owing to the foolish practice he had lately seen suggested, even in the *Times*, of having the wire tied to the railing of an area. If, in that case, the wire had been allowed to hang free, it could not have produced any injury. With the light, fine copper wires at present used, it was scarcely possible to conceive that if they did break they could produce any harm. Why, then, should legislation be enacted for such a minimum of accident as was shown by the statistics to which he had referred? granted that the wires were very ugly, and no one going through Moorgate Street or Leadenhall Street could help being vexed to see the metropolis so much disfigured. That, however, was not because the wires were overhead, but simply because they were carried in a higgledy-piggledy, spider-web fashion, in any direction, without method or system. If the corporations wanted to do good it should not be by trying to force the authorities to place the wires needlessly underground, but by trying to exercise some control over those who erected wires overground. It had been thought, from the remarks he had made about the gauge, that he expressed disapproval of the gauge recently introduced by the Board of Trade; that, however, was not his object. The gauge was a very good It had been accepted by nearly everybody; it had been authorized, and it would do a certain amount of good. But what the Post Office objected to was that there should be so many changes. When it was found that a wire which had been known by their men as No. 8, was called at another time No. 7½, and at authorities in improving the specifica- gave a higher conductivity than hard-Vol. XXXI.—No. 2—9

tion. (The copper wire was here tested.) It would be seen that the piece of wire experimented on had stretched 0.15 in 10.2 inches, or nearly 2 per cent. The other piece of wire was eighty-one thousandths of an inch in diameter, and it ought, by specification, to break at 320 lbs., which would be 27 tons on the square inch. It actually broke at 362 lbs., or 31 tons on a square inch.

Sir Frederick Abel, C. B., Honorary Member, said that his remarks should be mainly with the view of eliciting further information, and, if possible, of adding a few supplementary facts with reference to certain points dealt with in the paper. Reference had been made to the remarkably useful work done by the late Dr. Matthiessen, as far back as 1860, in regard to the influence exerted by different commercial impurities in copper upon its conductivity or electrical resistance. The author had correctly stated that those researches had not only greatly instructed them with reference to their knowledge of copper as an electric conductor, but had also led, in a very important degree, to improvements in the treatment of copper, with special reference to the production of electrical conductors. It was stated in the paper that Dr. Matthiessen had determined the electrical resistance of pure copper; but he was not quite sure whether, in the present day—twentyfour years after the experiments-whatever reliance might be placed on the results obtained, the measurements given could be accepted as truly representing what the resistance of perfectly pure copper should be. Electricians had acquired a considerable amount of additional information, and they were on the way to acquire still more in regard to the influence of very minute proportions of impurities upon the electrical conducanother No. $7\frac{3}{4}$, they decided, in order tive powers and other physical properties to avoid confusion, to abandon the gauge of metals; and no one could teach them altogether, and simply to speak of the more in that direction than Professor wire as of so much weight per mile. That Hughes, who had recently been pursuing method had been introduced into India some very remarkable researches. Therewith great success. He had stated that fore, although they still accepted with the great improvements in the manufac- great confidence the results of Dr. Matthture of iron were due to the care be-stowed upon the specifications of the au-more with regard to the conductivity of thorities at the Post Office. He ought really pure copper. In reference to the to add that the improvement was also manufacture of copper wire, the author due to the great care taken by the India had mentioned that soft copper always

drawn copper, its tensile strength being, of course, considerably lower. On that point he would ask the author to furnish additional data. In some experiments that he had made, which, though few, had been carefully conducted, he had found that the conductivity of a particular sample of copper varied but little, whether it is in the hard-drawn or in the annealed state. Dr. Matthiessen had mentioned that it varied about 2 per cent., but in some recent experiments Sir F. Abel had found that there was no practical difference between the conductivity of certain samples of copper, containing but a small proportion of chemical impurity, when this was in the harddrawn or the annealed condition. In one experiment, with a length of 15 feet 6 inches of copper, he had obtained 0.0257 ohm resistance with the harddrawn, and 0.02515 with the annealed. The very slight variations might almost be variations due to experimental error, even though when multiplied upon a statute mile the difference was more appre-Taking the numbers upon a mile of wire they would represent, in the case of the hard-drawn wire, 8.707 ohms, and in the case of the annealed wire 8.520 ohms, showing even thus only a very small difference. He might be allowed to allude in passing to what the author had said in reference to what appeared to be the influence of currents upon the durability Electricians had still of a conductor. much to learn in that direction. Many persons believed that important alterations in the physical structure of copper · and of metals generally, were effected by the continuous or intermittent passage of currents through them. He thought, with the author, that further information was necessary on that point. One thing was worthy of notice, namely, the influence of small quantities of impurities which would be detrimental to copper as a conductor, when contained in the india-rubber or other materials used as dielectric coatings. Minute quantities of sulphur, for example, in india-rubber, would find their way into copper wire given purity. coated with it, and exert a detrimental effect on the metal as a conductor. was that which led Mr. Hooper to devise ity of iron wire was maintained by galthe very pretty method—which, however, was only partially successful—of keeping method of treatment, he afterwards

tact with copper wire coated with it, by introducing india-rubber between the vulcanized rubber and the copper itself. As to the question of purity of copper, the author had referred to the very great advantage which had been conferred by improvements in the metallurgical treatment of copper upon the product, so far as electric conductivity was concerned. He had mentioned the "best selected" copper as the material which gave the best forms for wire which could be obtained until certain high qualities of copper were brought from Australia, Lake Superior, and other places. The quality of "best selected" copper, however, was very uncertain, because it was obtained by a somewhat rule of the thumb method, and it frequently contained proportions of impurities, detrimental to the conductivity of copper, fully as great as those which had been introduced in the production of some more recent wires, such as phosphor-bronze. One of the most important impurities in "best selected copper" was arsenic, and arsenic and phosphorus were about equal in their detrimental effect on the conductivity of copper. He should like some additional information with reference to the statement that electro-deposited copper had not the same mechanical strength as ordinary refined copper. He hardly thought that the author meant to refer simply to copper in the condition in which it was deposited. Electricians would not attempt to make wires by depositing copper in that form, and he did not see why copper obtained by electrolysis should not be as strong as copper obtained by other methods, because by re-fusing copper in a reducing atmosphere, and then converting it into bar and rolling and drawing it in the ordinary way, it was subject to the same mechanical treatment, and was obtained in the same physical condition, so that, whether it had been originally reduced by electrolysis, or by chemical means, there could be no difference, as far as he could see, in the strength of a wire of a

With regard to galvanized wires, the It author had pointed out that the durabilvulcanized india-rubber from direct con-stated that the zinc with which the wire

posed to the air, and that, since zinc ox- first sight important advantages as a ide was insoluble in water, the wire was conductor; so important indeed did they protected by an impervious coat. There, appear to be that the Royal Engineer as a chemist, he must join issue with the authorities, finding the material when author, though the point was not a very first tested to present such great adimportant one. The truth was that vantages over ordinary iron, and even oxide of zinc was by no means insoluble, over copper wires in many respects, inbut was actually soluble in soft water, troduced it into the service in some relike rain water, to such an extent, that cent campaigns. It was used in the galvanized iron could not be used with Ashantee and Abyssinian wars, and afteradvantage as a material for the construct wards in South Africa, and some was tion of tanks or conduit pipes where soft even sent to Egypt, though he believed into solution in so considerable a pro-portion as to exercise an injurious medi-objections advanced against it even as cinal effect upon the constitution. He recently as 1881, related simply to its thought that when galvanized iron wire being rather springy, and somewhat difwith a hard film of oxide, such as was found free from the liability to kink, uncertain in regard to stability; and able material.

He would next refer to an interesting form of conductor, of which those who had to construct military telegraph lines on active service had nad considerable experience, namely, the so-called compound wire produced by coating steel wire with a copper sheath, which was soldered to the surface by drawing the would be considered very short-sighted, steel wire through a bath of tin which for phosphorus was one of the elementary acted as a cementing or soldering ma- bodies about the most detrimental to the terial. In that way, as the author had conductivity of copper that could pos-

was coated became oxidized when ex- ance was produced, which presented at water existed, on account of zinc passing it had been returned thence in the same was exposed to the air it became coated ficult to bend, but on the other hand it formed when a sheet of lead, which was so that the one defect was counterbalalso an oxidizable material, was exposed anced by the other advantage. But after to atmospheric influences. That hard the material had been in store a few film protected the metallic coating, and years, and issued again for a special trial prevented further oxidation; so that the at Aldershot, it was found that when atzinc itself was protected by the super-tempts were made to put up a line upon ficial coat of oxide, which was only very which some strain was brought to bear, slowly removed by water, the zinc itself the wire broke in many points; indeed it remaining as a protective to the metal broke down utterly, and this was due to until the atmosphere plus water found the effect pointed out by the author, out some minute imperfection in the namely, that there existed here and there coating, and then, as soon as the smallest minute imperfections in the building up portion of the iron surface was exposed, of the wire, which, admitting the access the action established between the zinc of water and air, had established a corand the iron led to rapid corrosion. That rosion of the steel wire and brought was why, even in the absence of the acid about the destruction of the material vapors to which the author referred as destructive to the metal in towns, galvanized iron, not only in the form of disadvantage, namely, that when the wire wires but applied to other purposes, was had been roughly used there was a tendency of the outer sheath to peel off and there could be no doubt that galvanized injure the hands of operators handling iron, though it had been very useful, was it, and to be objectionable in many ways. on that account a comparatively unreli- It was for those reasons that the wire, which had been somewhat extensively used in the service, had been discarded.

The last class of wires to which Mr. Preece had referred were the bronze wires, the first of which was the so-called phosphor-bronze. Anyone first applying phosphor-bronze, correctly so called, to the production of a good conductor pointed out, a comparatively light and sibly be used, ranking equal with arsenic very strong wire of not very high resist- in this respect. In some of the early phosphor-bronze wires which he examined, over-estimated, unless special precautionhaving a resistance of about 49 or 50 ary measures were taken. The first wire ohms to the mile, there existed 0.22 and was the coarser one used for telegraphic 0.18 per cent. of phosphorus. But, as purposes, and it contained 97.75 per the term "bronze" implied, there was all cent. of copper, and nearly 0.25 per ways in those wires a certain proportion, cent. of tin. The finer wire contained a but only a very small proportion, of tin. After referring to these new kinds of namely, 3 per cent., and although it was wires as alloys and as bronzes, the author stated that phosphor and silicium-bronze evidence of the existence of silicium at were so called, not so much because all. those materials were mixed with the copper, but because they were used in the preparation of the alloy, and there was no doubt that to a considerable extent that was the case. Phosphorus was undoubtedly a powerful deoxidizing agent; and as oxygen was one of the important enemies to the conductivity of copper, the introduction of phosphorus by removing the oxygen would increase the conductivity of the metal or of its alloy with tin. But it was almost impossible to produce a wire first instance alloyed with the copper, from a metal treated with phosphorus, without leaving some traces of phosphorus in the material; hence one could quite understand how so-called phosphor-bronze, though superior in point of strength to copper itself, was inferior in regard to conductivity, and was found to be very variable, because it would be exceedingly difficult to produce phosphorized bronze or phosphorized copper at different times containing precisely or approximately the same proportion of The latest form of bronze phosphorus. wire, and the one to which the author had directed special attention, was the silicium-bronze, to which Sir. F. Abel's attention had also been directed when visiting the electric exhibition at Vienna. He there saw the very thin wires now used for telephonic purposes. He had made some experiments with two samples of silicium-bronze wire brought from Vienna, and the results confirmed the statement of the author that the term silicium-bronze did not at all correctly represent the composition of the material; in point of fact it was not to be assumed that it need contain any silicium at all. In one wire which he examined the amount of silicium was 0.005 per cent., and in another there was not a trace of silicium. It should be observed that in the presence of tin, the proportion of silicium was very liable to be apparently the strongest conductor of

considerably larger proportion of tin, examined with great care, there was no

Those wires certainly possessed all the properties in regard to strength and powers of elongation and conductivity which were claimed for them; but although it was probable and perhaps certain in the case of one of them that silicium might have been in some way concerned in its production, there was no positive evidence that it derived any valuable quality from the employment of that material, unless it were that, by some special treatment, silicium became in the and by its own subsequent oxidation abstracted the oxygen contained in the alloy, thus removing an antagonist to the conductivity of the material. At any rate it would appear that the electrical qualities and the strength of the wires. were chiefly due to the strength of the tin alloy used, and to the metal being employed in a hard-drawn condition. Both the wires were hard drawn when he received them. The tenacity of the coarser wire was from 300 lbs. to 325 lbs; its diameter was 2 millimeters, and its weight 100.5 lbs. per mile. After annealing, its tenacity was 190 to 200 lbs.; the finer wire had at first a tenacity of from 170 to 180 lbs., and when annealed, from 95 to 100 lbs. Although it was possible that silicium might have had something to do with their production, so minute a quantity as was detected by analysis in the one instance might have been purely accidental. It was possible that the chief merit of the process for producing the so-called silicium-bronze lay in the production of a wire consisting almost entirely of pure copper in a harddrawn condition, but with a small proportion of tin, giving it increased strength. There could be no doubt that pure copper in the hard-drawn condition, with the addition of a small quantity of

present acquainted. Professor D. E. Hughes perfectly agreed with Sir Frederick Abel with regard to the use of copper as a standard. His experiments on the molecular conductivity of copper neglected everything as to its chemical composition or its form, and simply regarded the structure of the material. He had a piece of pure copper given him by Prof. Chandler Roberts which he took as a standard, and the conductivity of some of the copper deposited electrically with a Daniell cell was 225, or more than double the standard of the Mint. That value did not perhaps represent the conductivity exactly, but he would say 50 per cent. higher value. It was found that if melted, it fell 50 per cent., and if re-melted it fell again. Whatever was done to change its molecular structure the conductivity fell. He therefore maintained that electricitydeposited copper was the very best form. If a wire could be actually deposited by electricity, it would be in the best form to conduct electricity. But that was not done. It was torn, and pulled, and twisted, and was no longer copper as it ought to be, but some changed conductor. The capabilities of any material in its pure state, and therefore the real standard, were not known. It could not, therefore, be said that the standard of copper was 100. Some experiments had been made by Professor Chandler Roberts and himself on bronze and tin alloy, and it was found that in gradually making the alloys there was a certain point at which a complete and sudden rise in value took place. He wished to ask the author a question with reference to conductivity. At present, in experimenting for conductivity, they used a Wheatstone bridge, and took the measure of the electricity after it had been flowing for a minute, or three or a stable condition; for telegraphic purposes which had been called in France the périod variable, which was not measured, but which was very

this class with which electricians were at interrupter, with a Wheatstone bridge having contacts two or three thousand times in a second, he would get some very valuable information of the kind that he required. He did not want to know what it would conduct five minutes after the battery was put on, but what it would conduct during the first portion of the contact. He did not agree with the Author in regard to overhead wires. As an old telegraphic engineer he remembered that the wires were constantly broken. But why did that occur? The Author had himself shown that the zinc became oxidized, and that, that particularly occurred in smoky atmospheres. Perhaps he thought that London was not very smoky, and therefore was free from danger. It was stated in the Paper that there was danger, not to the inhabitants, but to the life of the wire itself, and for that reason an effort had been made to get compounds of wire, copper and steel, which gave great promise. It was thought to be an excellent wire at first, but after four or five years its defects were discovered. Indeed the history of telegraph engineering as a whole had been to the present time a history of success; but it had also its history of failures leading on, like the Atlantic cable, to a greater success. Electricians commenced with bad conductors and bad insulators, and then they gradually improved them; but they had not yet attained perfection. Author now thought that the silicon wire was absolute perfection, and it had the appearance of it; but perhaps in four or five vears his opinion might be changed. At present he had no hope for overhead wires except in that form. He had stated that only two persons out of four hundred thousand killed by accident in thirty years had died from injuries received from overhead wires. The wires, however, had not been up during the whole of that time, having increased very rapidly of late years. four or five minutes, till it had arrived at But the danger from the wires was not at There was a period the beginning, it was when they were getting old and shaky; and at such time he confessed he would rather be out of London than in it. It was true that, thirty important for telegraphic instruments years ago, Germany, as well as England, when making, say, one thousand contacts had tried underground wires, failure being per second. There was a great difference the result; but this was in the early pebetween the results with the périod vari- riod of telegraphy, and sufficient care was able and the périod stable. If the Author not taken in the manufacture of the cables. in measuring his wires would use a rapid Since then, owing to the rapid extension

had been gained, so that the insulation of an underground wire was far better than that of aerial lines. The German Govground wires. At first their electricians at high speed; but in a very short time, by the adoption of the necessary electriland.

of submarine telegraphy, great experience eight years; and he could from that experience bring forward facts which would go far to support the Author's view as to the extreme desirability of adopting some ernment, after a series of exhaustive ex- other form of electrical conductor in prefperiments, decided upon the trial of a erence to iron wire, at all events for aerial direct underground line from Berlin to lines. He wished to look at the subject Cologne, the success of which had led to from the point of view of a colonial telea rapid extension in all directions, there graph engineer, because his experience being already some 15,000 miles of under- had been drawn from the colony of South Africa, with whose telegraph engineering had some difficulty in working these lines he had been connected during the period he had named. One of the main items of expense in that colony was transport. It cal conditions of contacts, reversed cur- was almost incredible for an Englishman rents, and polarized relays, they had been living in a thickly-populated country, and enabled to work their high-speed instru- with ample means of conveyance at hand, ments with far more regularity than was to appreciate the enormous difficulties in possible with the constantly deranged regard to transport in a new country. It aerial wires. After mature consideration, might be sufficient to say that the Coal the French Government had also lately Measures of South Africa were lying pracput their main lines underground, having tically dormant, and it was found cheaper some 7,000, miles which would be in- to import coals from Newcastle than to creased as rapidly as the finances would get them out of the bowels of the earth allow. In Paris as well as in London the 100 miles from the sea-coast. Again, tens telephone companies put their wires over- and hundreds of thousands of acres of head; and when he was at the Paris Con-splendid arable land were lying waste, and gress he said it was a great pity that such wheat could be imported cheaper from a beautiful city be disgraced by overhead South Australia or from the Peruvian and wires; that it did not much matter, per- Chili coasts than it could be brought from haps, what was done with London, but the place where the African lands were that there ought to be at least one city lying fallow. The cause of the difficulty free from the evil. All the overhead wires was transport. The same difficulty apwere afterwards taken down. The tele-plied to the telegraphic engineer in the phone people protested and declared that constructions of his lines. If a lighter the telephones would not work, and that form of wire were introduced having the they could not get over the induction. same electrical qualities as the iron wire They were, however, forced to put their employed at the present day, the transwires underground, and it was now stated port difficulty would be to some extent that they were working better than in any overcome. It was not so much the actother country. Berlin as well as Paris ual saving in the expense between a coil had suppressed all aerial lines in the city; of copper and a coil of iron wire of the and as the German and French electri- same electrical conductivity, although that cians had vanquished all electrical trou- was considerable; the great point was bles, he had confidence that the Author that the iron wire in telegraph construcwould equally solve the problem for Eng-tion was practically the pivot round which the other elements, as it were, revolved. Mr. J. Sivewright, C. M. G., thought It was what might be called the "indethere could be no question as to the im- pendent variable," according to the variaportance of the subject of the Paper. He tions of which all the other materials emcould not speak from the point of view ployed in telegraph construction would of a scientific man, or a manufacturer of also vary. A lighter telegraph wire meant telegraph wire, but he could relate his a lighter insulator. Less surface was exown experience as a practical man who posed to the insulator, and consequently had to do with electrical conductors, and a smaller insulator could be used, because to whom the objections to the present there was less leakage. And not only form of conductor had been forced home was there less leakage, but in regard to nearly every day during the last seven or electrical storms, the difficulties which

had to be faced were correspondingly di- be more easily turned into slugs or bullets minished. A lighter insulator meant a for his gun. With regard to the effects lighter pole; in fact all the plant of a telegraph line would get proportionately diminished in weight according as the gauge of wire was reduced, and with a reduction in weight followed a reduction in transport, so that a very great saving The coils of iron wire was effected. would be easier to handle, and there would be increased speed in the erection of the wire, attended with diminished cost. to the question of joints, every one concerned in the maintenance of telegraph lines knew what a bugbear joints were. Whether the wire was copper or phosphor-bronze, or silicium bronze, as long detect any flaw or mechanical fracture. as telegraph engineers in the Colonies got light, hard, durable, non-expansive, elastic wire, they did not care. They could get longer coils of it which could be run out to the extent, probably, of 600, 700, or 800 yards, but they were obliged to confine themselves to 500 yards (100 lbs. being about the average weight of the coils); not that manufacturers could not supply longer coils, but that length was found most convenient for handling. If they could dispense with a large number of telegraph joints, they not only saved in that way, but the maintenance became a far easier matter. Those were arguments which, from the colonial telegraph engineer's point of view, he brought forward in favor of reducing the gauge in telegraph wires. One objection that had been brought against the use of copper was that being of greater intrinsic value than iron, it would be more likely to be stolen. That was a specious argument at first sight, but Europeans, at knew that if a workman had good materiall events, who were inclined to thieve al he would make a good job, and if he would turn their attention to something had bad material he was likely to slur more portable and valuable, and less likely to be detected, than the telegraph stitious and wholesome dread of the wire, that was not only suicidal but criminal. he had the option, would prefer iron wire the second coil the silicon was 0.117, and

of galvanizing, he was not opposed to the process; nor would he express any opinion as to its value in countries where the same climatic conditions existed as in England. But he might mention that in South Africa a wire treated as he had described in a bath of oil was erected at least fifteen years ago; it had no galvanizing, but although they had had some splendid specimens erected since, he knew of no better wire than the one to which he had referred. He had examined a considerable proportion of its length within the last twelve months, and he could not It was ordinary soft wire, and had stood well. It was in a dry climate, with comparatively little moisture, with no smoke, and with none of the chemical causes which would affect ordinary wire. What had been said by the Author as to the necessity of rigid inspection almost amounted to a truism, at least he hoped it would be accepted as such; because there was probably no branch of science in which the old proverb was more applicable, "A stitch in time saves nine," than it was in regard to the selection of telegraph materials—not only the wire but all other requisites. Perhaps it required the experience of finding, 300 or 400 miles from the seaboard, insulators open, bolts missing, porcelain gone, iron bases fractured, and telegraph wire breaking in the workman's hands, to realise the enormous importance attaching to a rigid inspection of telegraphic materials. There was not only the value of the wire, but every one over it. In his opinion, therefore, any administration that neglected so vital a wire; while the aboriginal had a super-consideration would be guilty of an act

so that, in times of peace at any rate, he was hardly likely to meddle with it. Professor A. K. Huntington thought it might be of interest if he gave a few Until within the last two years, the South figures with regard to four specimens of African native respected the telegraph silicium-bronze wire which he had recentduring the war, but that respect had now ly examined. They consisted practically gone, and amongst the difficulties of tele- of nothing but copper, with the excepgraph maintenance the possibility of the tion of a small portion of silicon and tin. wire being cut and taken away had to be In the first coil there was a percentage faced. Still be thought that a native, if of 0.099 of silicon, and 0.079 of tin. In during the war to copper, because it could the tin 0.0017. In the third coil, silicon

0.1105, tin 0.014. In the fourth coil, sili-tion. Now, as the copper received from con, 0.0917, tin 0.099. In the second Australia had not been subjected to the and third coils the amount of tin was so "best selecting" process when in a state small as to be well within experimental of regulus, it followed that it would conerror, so that he was not prepared to tain any bismuth originally present in say whether the coils really contained the ore. He had been told by a very tin or not. From the examination of the large manufacturer that some copper specimens there was sufficient evidence which he had received from Australia, to lead to the supposition that a certain giving by analysis 99.67 per cent. of copamount of tin was present, at any rate in per, gave a very bad conductivity—sometwo of them. Whether that tin was thing like 30 as against 90 or 100. The simply an impurity derived from the result had been traced to the presence of ore, or whether it was the residue of tin bismuth. He had found, on further inwhich had been introduced during the quiry, that if there was more than 0.05 manufacture, he was not prepared to say, per cent. of bismuth present in copper as it was impossible to arrive at any con- its conductivity was seriously reduced. clusion on that point from a chemical examination of the wire. Silicon ap- had mentioned only to condemn the compeared to be present, and taking into ac-pound conductors which had been made count the supposed process of manufac- both in England and America, and he ture, there is no reason to doubt the ex- had condemned equally those of the past istence of a certain amount of it. He and of the present. He did not rise to had mentioned these particulars as bear-gainsay this, but simply to bring before ing out, to some extent, the results given the members some examples of the comby Sir Frederick Abel, but with some pound conductors now being made in differences in regard to the amount of America, and to say a few words with retin. With reference to the introduction gard to the method of plating in use of silicon, he had succeeded in introduction. He had had an opportunity during large quantities of that material into ing the last spring of passing through copper, and, in some cases, with a very the manufactory belonging to the Postal remarkable effect. As to the influence Telegraph Company of New York, at of arsenic on the conductivity of copper, Ansonia, in Connecticut, a concern which that, of course, was a substance which was making the same wire as that alwas one of the greatest culprits in de-ready laid between New York and Chistroying conductivity. But there was cago. The works were originally erected another which the author had not noticed, namely, bismuth, which he thought sonia, the well-known electricians, for the had even still greater effect than arsenic purpose of carrying out ideas which origin reducing the conductivity of copper inated with Mr. Farmer, but they had One of the countries to which the author passed into the hands of the Postal Telehad referred as supplying pure copper, graph Company rather more than a year Australia, had ores which contained an ago. The works occupied a space of 250 appreciable, and, in some cases, a consid-feet square, and there were in the builderable, amount of bismuth; and as the ing two hundred and fifty plating vats, copper was often sent in ingots, there which were supplied with current by was liability to trouble with the material twenty-three dynamos, driven by two enso obtained; because, although the bisgines, each of 300 H. P. It would give muth could be removed without difficulty some idea of the amount of current supin the "best selecting" process, due to plied to the vats if he stated that he saw the relative affinities of copper and bis- a carbon $\frac{7}{16}$ inch in diameter and 10 muth for sulphur, yet in refining, owing inches long deflagrated in the course of to the copper having greater affinity for a few seconds by a shunt so small that oxygen than bismuth, it was not practic- its abstraction from the general current able to remove the bismuth merely by could not be noted in the results of the oxidation, so that if much were present the quantity could be reduced but slight-troughs 20 feet long and 2 feet 6 inches he could make out, was due to volatilizathere lay longitudinally a horizontal cop-

Mr. D. Pidgeon said that the author by Messrs. Wallace and Farmer, of An-That which was removed, so far as either way. Over each plating trough

per shaft about 3 inches in diameter, stick, the coils of wire which were to be plated—as many of them as could be accommodated in the tank, the spires being separated by slips of plate glass, so of the coils hung outside the tank over coil of wire was screwed slowly through the electrolytic bath, and, after plating, hung again from the spindle, as the unplated wire did at the other end. This operation was repeated three times, the result being that 4,000 lbs. of copper were deposited daily upon 8 miles of wire. He held in his hand a piece of the compound conductor which had been thus three times screwed through the electro-It was 0.214 inch in diammile, and a tensile strength af 2,700 lbs., of which the steel contributed 1,700 lbs., and the copper 1,000 lbs. This wire was the same as that through which telephonic speech was readily heard between Chicago and New York, as readily (as he had been informed by a gentleman who listened to it) as if the length had been no greater than that of a room. also the wire upon which ten simultaneous messages had been sent-five each way—by means of the well-known Gray harmonic arrangement. It might be said that the wire was very expensive, if only 8 miles a day could be produced by the expenditure of such a force as he had mentioned. But the process did not stop at that point. It had been found that the cohesion between the central steel core and the copper envelope was so great that it might be passed through the ordinary wire-drawing apparatus, and the core and the envelope would be reduced together. He exhibited a wire which had been produced from the one he had al-This was 12-wire gauge, ready shown. outside diameter, while the steel core was 18 inch Birmingham wire gauge, and on examination it would be found that the steel core was perfectly central, with the copper surrounding it equally on all sides. Here, then, was a wire the exact equivalent, electrically speaking, of No. 4 iron wire, the largest now used in tel- works on the Continent which produced egraphy. It could be produced at the annually at least 500 tons of copper, and rate of 32 miles a day, and the cost, there were two works in this country therefore, was one quarter that of the that were being fitted with dynamo ma-

other. If that conductor came into use from which there hung, like rings from a it would be, in the first place, because its cost was so much diminished by the fact that it could be wire drawn, and in the second place, because the wire drawing gave to both wires a considerable increase as to prevent their contact. The balance in their tensional strength, and at the same time secured the conductor against the end of the shaft. Upon rotation, the the action of those atmospheric influences which the author had mentioned in his complaint of previous compound wires. This wire, although a compound one, was as capable of withstanding the attacks of the atmosphere as that of any wire drawn from homogeneous metal. He had a specimen of the joint which was employed in the wire extending between Chicago and New York. It was a copper ferule slightly flattened, and tinned by immersion. Into it had been thrust the ends eter, had a resistance of 1\frac{1}{2} ohm per of two wires, and the whole then dipped in a bath. Economically, the wire which he exhibited was the best which the Postal Telegraph Company had yet produced; but he was inclined to doubt whether, even taking into consideration the fact that plated wires could be four or six times increased in length, they could compete with the homogeneous wires of which the author had shown such extraordinary examples.

Professor Chandler Roberts thought there could be no question that pure copper was the best material to employ, because it was well known that a very small quantity of alloying metal caused the curve of conductivity of copper to fall rapidly; and it appeared to him that any increase of tenacity that might attend the union of copper with any other metal, not excepting silver, was dearly bought by the sacrifice of conductivity resulting from alloying the copper, and, as the electrician must have copper as pure as he could get it, any improvement in metallurgical processes for the extraction of copper from its ore assumed considerable importance. There were some facts connected with the electro-deposition of copper which had not been prominently noted in the discussion. He did not think that the scale on which the copper was now deposited electrolytically There were two was quite appreciated.

chines that would enable them to deposit copper at the rate of about 60 tons per week. He did not think it was quite understood that nearly pure copper could be thus obtained from very unsatisfactory ma-To take an extreme case, there terials. were before him some specimens containing several per cent. of arsenic, and yet, by solution and precipitation, an excellent variety of copper had been obtained from The author seemed similar specimens. to fear that electro-deposited copper did not possess the same tenacity as ordinary copper; but statements had recently been made in the continental scientific journals, especially by Austrian authorities, showing that electro-deposited copper possessed a very high ductility and considerable tenacity. At any rate, the copper was free from metallic impurities, so that even if it had to be melted the metallurgist had only to contend with the question of dissolved cuprous oxide, which, after all, was a very small matter, because it could be so easily dealt with. Copper was now electrolytically precipitated in bars, rolled directly into rods, and drawn into wire, which found a ready sale at remunerative prices; and it must be remembered that against the extra cost of the solution and precipitation of the copper by electricity there was a handsome set-off, in the shape of the precious metals recovered from the crude He thought, therefore, that the question might be safely left to metallurgists, who would have no difficulty in supplying the electrician with pure cop-manganese. The second contained 3 per per at a remunerative rate. had asked him to say a few words about made into rods, and drawn into wire, the the deposit of iron by electrolysis. It highly manganiferous pig produced an was well known that the late Professor iron containing 98.871 per cent. of metal-Jacobi and Dr. Klein, of St. Petersburg, lic iron, and 0.49 per cent. of manganese. had taught how to deposit iron of great The other sample of iron containing 3 purity, and with considerable facility. per cent. of manganese gave 98.89 per That iron, he was sure, would not com- cent of metallic iron in the wire, and only pete for electrical purposes with the ex- 0.184 of manganese, yet the mile-ohm retraordinary soft and pure varieties of iron sistance had risen to 5921.8. which could now be produced by ordin- those circumstances he hardly thought ary metallurgical means. The author that the Author was justified in laying had alluded to the effect produced by the whole blame upon the manganese. silicon in alloy with copper, and it had He did not think that the manganese had been stated that $\frac{9}{100}$ per cent. of silicon much to do with the result. might be retained by copper. He should like to mention, because he did not think it was very clearly understood, that sili- in the conductivity of copper wire, and

alloy of gold and copper containing 90 per cent. of gold fused at about 940° Centigrade, and, if it contained only 15 per cent. of silicon, its melting point was so much reduced that a strip would bend and fuse in the flame of a candle. Hence it was that the presence of a minute quantity of silicon might be of the greatest importance in modifying the physical

constants of pure copper.

He spoke with very little knowledge of the ordinary methods of electrical testing, but he did not think that the extreme delicacy of the induction-balance of Professor Hughes was quite recognized. He had some specimens of copper, which in regard to analysis were identical, and yet when disks of each sample of metal were treated in precisely the same way, mechanically and thermally, they showed a wide difference when submitted to this beautiful instrument, which would be a powerful ally in future, both of the electrician and the metallurgist. The principal point, however, to which he wished to direct attention was, that the metallurgist could supply the electrician with pure copper at a reasonable cost.

Mr. W. Carson desired to say a few words with regard to the effect of the presence of manganese, even in small percentages in conductors, upon the conductivity of the material. He had obtained two samples of puddled iron, from each of which he had made a number of tests. The first sample was from a highly manganiferous pig, with 6 per cent. of The author cent. of manganese. On being puddled,

Mr. J. Thewlis Johnson said the Aucon had an extraordinary effect on many had intimated that the improvements in of the alloys of copper. The ordinary iron wire had been forced on the makers,

who had not sufficiently availed themselves of the services of the chemist. 1857 a relative of his, with the late Dr. Calvert, made a great many chemical experiments on pig iron, especially as to the changes in pig iron when being converted into wrought iron for wire purposes. The notes were published in the "Philosophical Magazine," in 1857, but the pecuniary results had been very small. Since then some of his friends had, like himself, taken a great deal of pains in conducting chemical experiments, but as far as his own results were concerned they had not been very considerable, and he had come to the conclusion that no iron wire could be made giving a less resistance than what was at present obtained. The difficulty of the iron-wire manufacturer had been to produce a material which would yield certain mechanical and electrical tests. The specifications recently drawn up were a great improvement on those existing twenty years ago, and the examinations were conducted on a rigorous and fair system. He thought it was generally admitted in the trade that manufacturers all knew what wire would give certain results, and the examining officer in making his tests soon found whether he would be able to pass the wire or not. When he had made a few tests he knew pretty well that if the remainder of the wire was of the same character it would either be all passed or all rejected. No one more than the Author had impressed upon wire manufacturers the necessity of endeavoring to improve the conductivity of iron. season and out of season he had urged it upon them, and the result was that they were now all producing an iron which gave, ton for ton, a better average of conductivity or a less resistance than was obtained twenty years ago. But he wished to direct attention to the fact that while it was perfectly true that the iron wire used in England had decreased in resistance from about 15½ ohms in 1873 to $11\frac{1}{4}$ in 1883, low resistance wire had

was no stipulation as to the conductivity of the wire; but it was stipulated that the wire should be manufactured in a particular way, which gave certain high mechanical tests, and also the conductivity tests which the Post Office now de-He could give many other manded. instances, but he would only mention the line crossing the continent of Australia. erected in 1871. It was an unfortunate thing for the credit of England that the introduction of the conductivity test in the specifications, although advocated so long by the Author, did not first take place in England, but in America, by the Western Union Telegraph Company. He hoped the members would not leave with the impression that the days of iron wire as an electrical conductor were numbered. He had listened with great interest to the remarks on the process of depositing copper on steel, and he had been astonished by the statement that during the process of drawing wire when the copper was deposited on the steel the diameters of the steel and the copper were reduced equally. But for that statement he should certainly have doubted the fact. He believed that in practice it would be found that the deposited copper-coating would occasionally break in the process of drawing, and further, that as wire when drawn down became harder, and had to be annealed before the process could be repeated, a difficulty might arise in annealing a compound wire composed of steel and copper. The experiments with phosphor-bronze wire and compound wire, according to the Author, had not resulted satisfactorily, and there were only two other conductors, both of which were so expensive that economy compelled them to be used with a very small diameter. It was asserted that No. 14 copper wire, costing £87 a ton, was as efficient a conductor as No. 8 iron wire, costing £20, and that, mile for mile, it was not more expensive. That might be so, but he questioned whether it would be found as economical in practice. He thought that been a regular article of commerce long when it was scattered all over the country previously. He knew that in 1862 some a good deal would be stolen. At Vienna 2,000 miles of wire were sent from Eng- there had been a large exhibit of siliciumland to the French Telegraph Adminis- bronze, the cost of which he was told was tration, and it was identically the same £162 a ton. It appeared to him that it as that now used by the English Post would make a very charming toy line. It Office. In the specification of the French was never used till November 1881, when Telegraph Administration in 1862 there the first quantity was sent by the French

He Administration for an experiment. had seen no statistics as to its life. In India, monkeys often sat on the wires, and in the Colonies the birds flew against them, and he did not see, under such circumstances, how telegraph wires were to be maintained if they had only the diameter of pins and needles. Whatever conductors were employed, he thought they ought to have a good substantial diameter if the lines were to be maintained for any

length of time. Mr. A. J. Bolton exhibited some samples to show the process of manufacturing copper wire. The Author had referred to the rapid strides which had been made in improving the quality of conductors for electric currents, but these had also been greatly improved in form. It was often a great advantage to the electrical engineer to have the conductors of great length, and that object had now been accomplished. In 1850, when Mr. Charlton J. Wollaston, the electrical engineer of the experimental cable laid between Dover and Calais, came to his office with the order for the copper wire for the core of the cable, he was imperative that it should be made in continuous lengths to weigh about 30 lbs. in each piece. At that time, the only wire produced in copper of that size weighed about 4 lbs. in continuous length; and the foreman who was sent for to receive instructions, when he heard what was required, said, "Does the man think I am a fool?"—so impossible did he consider its production. At the present time continuous lengths were commonly made, with copper wire of the same diameter, weighing 70 or 80 lbs. The Author had stated that conductors for cables and electric light mains should be constructed with the purest copper producible. That object had been attained, and the samples on the table tested over 99 per cent. by Matthiessen's standard.

manufacturer to the Austrian Telegraph gauge, which had a resistance of 103 ohms per mile, had a breaking-strain of 255 lbs., and the cost was only 65s. about the same as that of ordinary iron

telegraph wire 0.171 size.

It would be seen from the table of the Author's experiments with silicious bronze that the 0.081 wire, with a resistance of $8\frac{1}{2}$ ohms per mile, gave only about an equal breaking strain to that of hardened copper of the same gauge, and the cost was about £6 per mile. It appeared, therefore, that hardened wire of high conductivity answered all the ends, and the breaking strain was a very good one, 340 lbs. being sufficient for all purposes. The objection to the introduction of phosphorus or other materials was, that results were never uniform; but with wire of high conductivity the results were always exactly the same. When silicon was introduced conductivity was wanting. The Author's next requirement was a low inductive capacity. That, he believed, would only apply to cables or insulated wires placed underground. Next, that the conductors should expose to wind and snow the least possible surface. course the lower the resistance the less the diameter of wire necessary to pass the same current, and therefore the wire of high conductivity would seem best to accomplish that end. The last requirement was that the wire should be practically indestructible. In that respect he thought that copper had everything in its favor. He might instance the case of a wire that had been more than twenty years over his own works; it had been constantly used for the passing of electric currents, and it had not altered in its conductivity or in its diameter during that period. As to coating steel wire with copper, and then drawing it down to make a conductor, reducing the diamater both of the steel and the copper, he too was much astonished. In his own works With regard to aerial lines there might it was a common thing to put a steel be some question. In his own works it mandrel inside a copper tube, and to had been found that in attempting to im-draw the tube down; but the mandrel prove the tensile strength by introducing always remained the same diameter. He any foreign substance into the pure cop-could hardly understand how the result per there was a loss of conductivity. The that had been stated could be possible. 14-gauge hardened-copper wire with high To get wire of high conductivity it was conductivity gave a breaking-strain of 340 essential that the ores, or the copper bars lbs., and a resistance of only 8 ohms to imported from Chili should contain as the mile; the weight per mile was 103 few alloys as possible, as then there was lbs., and the cost about £4. A wire, 15 not much oxidizing required in the refining process. The copper was cast in large bars (of one of which he held in his hand a section). These were rolled into long strips like the specimen exhibited, and then passed through a series of circular steel cutters, which cut them longitudinally into narrow pieces, each of which was passed edgeways through grooved rolls, forming a nearly circular bar of copper, which was subsequently drawn down to wire of the required size. The process was different from the manufacture of iron wire, which was not slit but rolled down into a thin rod from a large bar. He also exhibited some specimens of hardened copper wires which had been subjected to different tensile strains, showing the diminution that had taken place in size, but they generally secured a breaking-strain of 340 lbs., which was found to be practically sufficient.

Sir Frederick Bramwell, Vice-President, said it appeared Mr. Bolton, like Mr. Johnson, was surprised that the two metals in a steel wire, coated with copper, when drawn should draw uniformly, and in support of his doubts had referred to the fact that, if a steel mandrel were put inside a copper tube, there was no elongation of the mandrel when the two were drawn together. That was perfectly true; but it should be remembered that in that case there was no metallic attachment of the mandrel to the tube. wished to remind the meeting of a cognate instance in rolling-that when lead and tin were cast together in two thicknesses, to make Dobb's metal—it was formerly alleged that these two metals would not roll out uniformly; but, as a matter of fact, in whatever proportions they were cast -3 to 1, or 4 to 1-the rolled-out sheet showed the same proportion, although the metals were so dissimilar in their powers of yielding under the roll.

Mr. James Rock said he should like, as representing a company which manufactured both phosphor bronze and siliciumbronze, to say a few words on the subject under discussion. With reference to the uniformity of manufacture of alloys of copper, especially with silicon and phos-

products as well as Mr. Bolton could for that of the copper which he had produced of such excellent quality. French manufacturer of silicium-bronze, who was also the inventor, supplied large quantities to the French and other Continental Governments, and he guaranteed and produced it of certain degrees of conductivity and tensile strength. So far from silicium bronze being at present only a toy, on the Continent it was interfering largely with the use of iron wire for telegraphs. That was not the case in England, because the material was comparatively new. The analyses of Sir F. Abel and Professor Huntington confirmed the analyses in his own possession of similar alloys. There was, however, an apparent discrepancy with regard to the quantity of tin in the specimens. It was part of the process of manufacture that the proportions of tin and silicium should be adapted to the special uses for which the wire was intended. They accordingly produced two special kinds of electric conductors, one of high conductivity for telegraphs, and one of lower conductivity, but much greater strength, for telephones. The wire for telephones was largely used in England. It had very great tensile strength—as great as that referred to by the Author in connection with the telegraph wires for the Mumbles. It had similar properties to those wires, but a much higher conductivity; instead of 20 per cent., it had from 36 to 40 per cent. The apparent discrepancy between Sir F. Abel and Professor Huntington was probably due to their having analyzed examples of different constitution, one the telephone wire, and the other the telegraph wire. It was possible to produce silicium-bronze of different degrees of conductivity and of tensile strength. If electricians and engineers would only say what amount of strength and conductivity they required, the proportions could be adjusted accordingly. product was a very valuable one, and the analysis of one specimen should not be taken as representing silicium.bronze generally.

Mr. Frederick Smith observed that the manufacturers of iron wire had not failed phorus, it was part of the process of his to make use of the services of chemists company to manufacture those metals in in endeavoring to improve that material. strictly uniform proportions, and he It should be borne in mind that the could answer for the uniformity of the manufacturers of copper had a very different material to deal with at the out-cently tested a sample of hard-drawn set, and the same advance therefore copper wire, and had found that the ought hardly to be expected from iron-mechanical properties were inferior; it wire manufacturers. however, had been made, and he thought ping round its own diameter without that the resources of civilization were breaking. That was a test which all hard not yet exhausted even in the improvement of iron or steel wire. He had been bore only about $\frac{1}{2}$ per cent. elongation, testing some samples of an English made which an inspector would put down as steel wire, which gave as high a degree nil, after allowing for the fracture itself. of conductivity as those of any Swedish charcoal iron he had tested, together with a much greater breaking strain, and a in 6 inches. The size of wire that he higher degree of torsion. The six samtested was 0.81, about No. 14 W. G., ples yielded the following results: Diam- which was about one-quarter of the eter 209, resistance, 8.13 ohms; diameter weight of iron wire of the same conduc-208, resistance, 8.79 ohms; diameter 208, tivity. Instead, therefore, of being only resistance, 7.98 ohms; diameter 209, resistance, 7.23 ohms; diameter 209, resistance, 7.74 ohms; diameter 209, rethe cost of the line made of copper sistance, 7.98 ohms. The samples were all tested in the bright hard state previous to galvanizing. After galvanizing, the improvement would be about 0.3 ohm per mile in each case. That was posts, and any substance thrown against practically a new material. All who had worked for the specification for which the wire was used would know that a practically new material had to be made in order to meet the requirements. Instead of taking a material that already possessed a high degree of conductivity, the manufacturers had to take a material wire would not possess sufficient ductilthat gave a very great degree of resistance, and to bring it up to a high degree of conductivity; and they could only do that by making use of the services of chemists. With reference to the adoption of copper and phosphor-bronze or silicium-bronze, it should be borne in mind that a telegraph wire had a double function to perform. If it was simply a conductor and had only to carry the current, the wire with the highest degree of the tin being removed by contact with conductivity would undoubtedly be the best to employ; but the wire had not only to carry the current, it had to carry per would bear the same kind of treatitself; it had to be out in all weathers, over very long distances, through all kinds of country, and it had to encounter all kinds of risks. It was necessary, therefore, that it should have a certain amount of bulk. Much had been said about wires breaking down, but if wire was used of the kind that had been so made on all sides. He was glad of the highly praised, he thought the number of opportunity of speaking of iron wire bebreakages in all parts of the country fore it became a thing of the past, which

Great progress, would not stand wrapping and unwrapwires ought to stand. The material The breaking strain also was very slight, and it would only allow fourteen twists would be twice that of a line made of iron wire, so far as the wire was concerned. It was also exposed to great risk from the slightest motion of the it caused it to break immediately. In hot countries, where perhaps the wire would be most used in consequence of the great cost of transport, the results of changes in temperature might be very serious. The sun was very hot by day, and the nights were often cold, and the ity to stand such changes in temperature, which might cause it to snap. Johnson appeared to think that in the manufacture of compound wire, the steel would not be reduced at the same time as the copper or to the same extent. might be permitted to remind him that it was the custom amongst wire-drawers to draw wire coated with tin, and both were reduced at the same time without the draw-plate. If so soft a metal as tin could be so treated he thought that copment.

Mr. J. H. Greener had been connected with telegraph works for nearly forty years, and most of his time had been spent in erecting lines and supervising for different administrations. stores Meanwhile great improvements had been would be greatly increased. He had re-seemed to be the hope of the manufacturers of copper and bronze. Twenty thought it might be interesting to asceryears ago iron wire weighing 600 lbs. to tain whether there was any change in an the mile would not bear the strain of ordinary commercial cable which had 1,000 lbs. without breaking. present day, with the same wire a break-some time, and he had for this purpose ing strain of 2,000 lbs. could easily be tested a cable through which a current obtained. The Post Office specification had been flowing for nine months, say required a wire of very fine material, all about sixteen hundred working hours. most pure iron, because, working as they The electromotive force was 1,000 volts, did duplex and quadruplex, the authorithe size of the cable 7 strands, No. 16 ties wanted high conductivity. The B. W. G., and the current 10 amperes. He specification for the India Office re- tested the resistance carefully, and comquired for a wire of the same size 350 pared it with that of a cable of similar lbs. more breaking strain. The extra design which had never been used, and breaking strain had been a great bugbear he could find no difference. He then to the wire manufacturers. They could had the fracture examined microscopicaleasily give the 350 lbs. additional break- ly, and he could detect no signs of briting strain, and also the capability of sustleness. The cable had only been working taining fifteen twists in a length of 6 a comparatively short time, and the curinches, but when the conductivity test rent therefore was very small in proporwas also applied they had a very difficult tion to the area, about one-fourth of what task to perform. It had been accomplished, but to effect this the aid of the as allowed by the Board of Trade, 2,000 chemist had to be called in, because the amperes per square inch of section. If a wire manufacturers found that it would not pay to go on with the rule of thumb methods previously in use. He had with him some tests of the wire made by different firms during the past year. In the wire made by No. 1 firm, the average breaking strain was 2,196 lbs.; No 2, 2,123 lbs; No. 3, 2,150 lbs.; No. 4, 2,195 lbs. This uniformity was astonishing. Those results had not been achieved without a great deal of hard work, worry, and anxiety on the part of the manufacturers, who, in carrying out the great nuisance, but they had certainly helped him in every possible way.

Mr. Killingworth Hedges desired to

which had an alternating current passing through them, became brittle. He had

In the been carrying a current of electricity for the maximum current might have been larger current had been used there would probably have been some heating, as Dr. Matthiessen, in his contribution to the Royal Society,* had shown that if heating took place in a copper cable of a certain degree of impurity, there was an alteration in its conductivity, and he had quoted the case of a very impure piece of copper, which increased in resistance 0.064 per cent., after being heated to 100° Centigrade for three days. Dr. Matthiessen's experiments only went as high as 100° Centigrade, but Mr. Hedges specifications, had always been willing to thought he would go as high as he could render every possible assistance. No in heating various wires of pure metals doubt they had often thought him a and alloys by a current of a secondary battery, and the results were stated in the annexed table.

The first column showed the material say a few words on the effect of powerful used; the second, the resistance before lighting currents through a copper conheating; the third, the decrease of resistductor. It was most important that en- ance after heating; and the fourth, the gineers who had to do with electric approximate temperature as nearly as it lighting, and local authorities who pro- could be obtained. The experiments posed to purchase expensive copper tended to show that the pure metals uncables and lay them down to distribute derwent no change in resistance after electricity in their districts, should be being heated twenty-four hours; but certain that the passage of a powerful current had no effect on the conductivity purity decreased in their resistance and of the wire. He had noticed, as men-increased in conductivity. The decrease tioned by the Author, that wires taken was very small and was most noticeable in from dynamo machines, especially those No. 3, the tin alloy, to which he desired to

^{*} Phil, Trans. 1864, vol. 154, p. 167.

Materials.	Resistance.			
	Before Heating.	Decrease after 24 Hours.	Temperature. Fahrenheit.	
No. 1. Tin wire. No. 2. Lead. No. 3. Tin alloy. No. 4. Copper. No. 5. Tin-foil. No. 6. Albo alloy.	0.815 0.835 0.870 0.810 0.860 0.835	0.003 { 0.005 } { in 3 hours } 0.005 No change	390 590 490 1,900 400 1,200	

draw attention. case was only carried on for three hours, creased 7 per cent. He could not carry it on longer because the alloy melted, probably by the decrease in resistance allowing a larger amount of current to This alloy (tin and lead) was well known in the form of solder, which was largely used for jointing electric-light wires. It was dangerous to rely on solder alone because it would be softened by the passage of the current if there was any heat caused by a slightly imperfect joint, and an action would then go on which he thought had a tendency to reduce the metals into their constituent parts, so that by degrees the two wires would come a little apart, an arc would be formed, and the joint destroyed. All joints for electric lighting purposes ought to be made mechanical under considerable pressure, the solder should only be used to keep away the air. It would be interesting if the Author would give his experience of the joints used by the Post Office, also whether there had been any variation in resistance after they had been employed a long time. The question of joints was most important for electric lighting. ical work into electricity, and the problem draulic mains. conductors and their joints. Now it was required in a perfect conductor that the current in its passage should develop no light. The Author had suggested a possible variation of resistance due to tem- were, moreover, very often misapplied. perature of 20 per cent., between summer | Sir William Thomson arrived at a result

The experiment in that and winter. He hardly thought that would be the case in England. In some by which time the conductivity had in-climates perhaps there might be that amount of variation if overhead wires were used for electric lighting purposes, but if they were placed underground he did not think they would be subject to as much variation in temperature as were ordinary gas and water pipes, in that they would be surrounded and carefully insulated by some material which not only was an insulator of electricity but a nonconductor of heat.

Mr. T. H. Blakesley considered that in view of the large outlay which would probably take place in conductors for the distribution of electricity for electric lighting or other purposes, the Author had passed rather hurriedly over the law of economy which Sir William Thomson was the first to suggest. He ventured to recall the attention of the Institution to that point, first because of its great importance, secondly because the Author had somewhat imperfectly quoted the law, and thirdly because that economy was in practice very rarely carried out, it being generally thought advisable to save present outlay at the expense of future current expenses. The problem of course, was analogous to Dynamo machines afforded a most eco- the one which engineers constantly had nomical method of transforming mechan- to encounter in pumping through hy-If the main was conof using the current of electricity and distracted too much, there was a saving in tributing it successfully appeared to him the expense of pipes but a loss in the to be in the cost and the efficiency of the current expense of pumping. There were two forms of the law usually given, one that which had been stated by the Author, and the other asserting that the current heat until it arrived at the lamps, where should be always proportioned to the the heat would be utilized in the form of sectional area of the conductor. Both statements were somewhat imperfect, and

giving about 322 amperes to the square inch of conductor of copper, when the price of the copper was £70 a ton and 5 per cent, interest was allowed on the outlay, and the time during which the current flowed was one-half, or twelve hours a day. The late Sir William Siemens, in his address before the Society of Arts, arrived at the value of 390 amperes per square inch, taking £90 as the value of copper per ton and 7½ per cent. interest on the outlay, and one-third of a day, or eight hours in twenty-four, as the time of working. All these changes tended in the same direction. Now 390 did not materially differ from 324, and even one of the alterations which he made was sufficient to account for the difference. The reason why the divergence was so small was that he had put the cost of energy at 12d. per 10 Board of Trade units, which most people thought very high. He had used what would correspond more to the price of energy than to the prime cost; but in that problem no doubt the prime cost was the thing that should be taken into consideration. But whatever the values of these quantities, Sir William Thomson's law was only applicable to conductors where the expense of the conductor varied with the weight of it. doubt in telegraph wires that was approximately the case; but in the distribution of electricity on a large scale for electric-lighting purposes, or for the transmission of energy, the conductors were insulated, and probably underground, and on comparing the price of a bare conductor with its cost when highly insulated, it would be found that the price of the insulation was in excess of that of the conductor itself, for ordinary conductors, say of a $\frac{1}{4}$ square inch section, and that the extra expense of insulation did not vary anything like according to the section of the conductor, but more nearly as the diameter of the wire, or as the virtual diameter in the case of a bundle of wires. That would greatly modify the law as usually quoted for a proper economical system. outcome of the calculation in this case was that there was no longer the constancy between the current to be carried, and the sectional area to carry it, which was so often quoted. Another outcome Vol. XXXI.—No. 2—10

much higher than that given by Sir William Thomson or by Sir William Siemens. He had ascertained from the prices of a well-known manufacturer, that, with a conductor thoroughly insulated with gutta-percha and covered with jute and tape in sections ½ square inch, and employed for twelve hours in twenty-four throughout the year, there ought to be 566 amperes per square inch passing through it; for less sections of conductor more could be put through a unit of section. This rate per square inch increased sensibly, though not largely, as the sec-

tion got smaller.

Mr. W. H. Preece, in reply, observed that Sir Frederick Abel questioned the difference said to be found between the conductivity of hard-drawn and soft copper; but his own figures showed that it was 2 per cent. in favor of the latter, and this corroborated the accepted figure. He still maintained that iron manufacturers had not sufficiently brought to their aid the talents of the chemist. At the present time they absolutely did not know what was the conductivity of pure Professor Chandler Roberts had kindly offered to supply him with a piece of pure iron, but it was not certain that he had a piece to supply. Indeed, he did not know that a piece of pure iron had ever been seen. If anybody would supply electricians with absolutely pure iron, they would be delighted; at present they did not know what resistance it gave. It was true that Professor Hughes, with his exquisite little instrument, had told some curious stories about the internal arrangement of molecules, and he was prepared to assert that certain specimens were 225 times better than certain other specimens. He had not mentioned, however, how to obtain iron of sufficient purity to make perfect magnets and perfect wires. the question of iron bars and copper wires, Professor Hughes had suggested that the probability was that after five years' experience copper wire would be rejected, just as compound wire had been. In England the requisite five years' experience had been obtained; and electricians certainly had not arrived at the conclusion that copper was a better conductor for overground purposes than iron, without long experience and very rigid pracwas that the number of amperes that tical tests. They now had copper wire, might be put through a square inch was not in pounds or in miles, but in hundreds

of miles scattered over the country, and overhead wires was, he considered, a the result of their experience had been senseless proceeding; it meant additional to show that for certain purposes (he did expense, and it did not remove danger. not say for all) copper had a greater Who cared about the appearance of wires superiority over iron than some of the in a country district? No doubt many of speakers would be inclined to believe, the streets in London would be consid-Mr. Johnson appeared to think that cop- erably beautified if some of the numerous per would be stolen, but that had not wires were removed; his remarks, howbeen the result of past experience. As ever, did not apply to the city of London, to monkeys climbing upon wires, those but only to outlying districts. animals, like iron-wire manufacturers, had local authorities needed was power to increased in intelligence. In the early control the erection of overhead wires, days of telegraphy they did climb upon not necessarily power to forbid their the wires and break them down, but they erection. In all large cities and towns did not do so now. Perhaps the differ- the Post Office put the wires underence was due to the fact that the first ground, not to diminish danger, nor to telegraph wires were made of thick iron improve appearances, but for convenience rods, while the more recent wires were much finer, and the finer they were the less likely monkeys might be to perform gymnastics upon them. He was sorry that Professor Hughes differed from him not intend to put them there unless it on the subject of overhead wires. He believed that all electricians were agreed upon one point, that whatever the merits or demerits of overhead wires, they were better adapted for high-speed apparatus and general telegraph work. There could be no doubt that if a wire were extended between London and Manchester it would be commercially sixteen times worse underground than above ground; and to try to force an Administration like the Post Office to put its wires underground, because of some imaginary danger, was as absurd as it would be to try and force every railway company to tunnel underneath the roads instead of crossing them by bridges. It had been said that overhead wires were dangerous, but, as he had asked before, where was the danger? There was much more danger in opening trenches. The number of accidents from the latter cause very far exceeded those from falling wires. As to the question of economy, those who had to spend the money were, he thought, the best judges on that point. His remarks, however, applied to outlying districts. The parish of Wandsworth, for instance, wanted wished to apply it, and who possessed the a fire telegraph and a police telegraph; current prices of materials. The subject the Post Office authorities wished to put had been more fully worked out by Mr. the wires overhead, and the Wandsworth T. Gray. He however agreed with Mr. Board tried to force them to put them Blakesley, that the number of amperes underground: the postal authorities had per sectional area which could be transresisted, and the matter was now before mitted with safety and economy was a court of law. The opposition raised in greater than that given by Sir William many of the outlying districts against Thomson and the late Sir W. Siemens.

and economy; they had even an underground line between Liverpool and Manchester. Wherever it was necessary the lines were put underground, but they did was absolutely necessary, and they were not to be forced to do so by any absurd mania on the part of the local authorities. The important question of joints had been raised by Mr. Hedges; but there was one that had been settled long ago by telegraphists, it was, that the telegraphic joint as now constructed was perfect. In his long experience of thirty years, and he could appeal to those who could speak of a still longer period, the existence of a bad joint in a line properly constructed by an experienced man was absolutely unknown. He had seen, however, in lines used for electric lighting, most inefficient joints, and it was a matter of surprise that many of the electrically lighted pubhe buildings had not been destroyed by the utterly unsuitable wires that had been employed. There had been serious accidents, and there would be more unless electric-lighting engineers took a little more to heart the lessons of experience on this point. He had been contented with quoting in its broadest sense Sir William Thomson's law, leaving the results to be worked out by those who

EXAMINATION OF THE FORMULÆ USED IN CALCULATING THE PRESSURES IN STONE WORK.

By E. SHERMAN GOULD, C. E.

Written for Van Nostrand's Magazine.

this Magazine, I gave the two fundamental Using French measures, the elementary formulæ used in determining the maxima pressure would be given in kilos. per elementary pressures upon the base of a dam or other structure of masonry as follows:

$$(1) p=2\left(2-\frac{3u}{l}\right)\frac{P}{l}$$

$$(2) p = \frac{2}{3} \cdot \frac{P}{u}$$

These formulæ are of the utmost importance; they constitute the foundation of the entire theory of high masonry dams. They were given in the article named without demonstration—their general acceptance by the highest mathematical and engineering authorities seemed to render anything beyond their mere enunciation unnecessary. Enquiries and criticisms which have since come to my notice, however, suggest that some further examination of them may prove of interest.

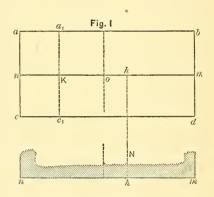
For this purpose I cannot do better than present a translation of Debauve's investigation and discussion of these formulæ, adding a note here and there which may be useful to those who approach the subject for the first time.

Mons. Debauve treats of the matter in his work upon stone bridges (10th fascicule of the "Manuel de l'ingénieur") under the head of abutments. I proceed to translate, commencing at page 109 of the above.

Problem.—Being given a homogeneous mass of masonry (Fig. 1) with vertical sides and a rectangular horizontal section abcd, the base being pressed by a vertical force N, the point of application h of which is situated upon one of the axes of symmetry of the rectangle, it is required to determine the elementary pressure at any point of the rectangle, and particularly to determine that point at which such pressure is maximum.

Note.—By "elementary pressure" is meant the pressure per square unit, ex-

In an article published in the April No. of pressed in any given standard of weight. square meter, which would, however, be generally reduced to kilos, per square centimeter. Using English measures, it would be given in lbs. per square foot, usually reduced to lbs. per square inch. By "one of the axes of symmetry" is meant the line nm (Fig. 1) which divides the rectangle into two equal parts.



In chapter I. of his "Cours de méchanique appliquée," Mons. Bresse solves completely the above problem by a consideration of the centers of percussion. We cannot here present this elegant and interesting investigation. The results reached by Mons. Bresse are given at page 62 of his treatise, and are as follows:

1° When the point of application h of the vertical pressure N is such that its distance oh from the center of the rectangle is less than one third of the half axis om,

if we represent the ratio $\frac{oh}{om}$ by n, and the

surface of the rectangle abcd by S, the maximum pressure will occur at the edge bd of the rectangle, and this pressure per unit of surface will be given by the formula

$$(1) p = \frac{\mathbf{N}}{\mathbf{S}} (1 + 3n)$$

2° If on the contrary the ratio $\frac{oh}{cm}$ is

greater than one third, the maximum pressure still occurs at the edge bd, but its degree is given by the formula

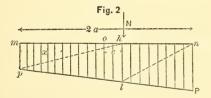
$$(2) p = \frac{\mathbf{N}}{\mathbf{S}} \cdot \frac{4}{3(1-n)}$$

In the first case the entire surface abcd sustains pressure; when the ratio n becomes 1, the entire surface is still pressed, but the pressure is nil at the extreme edge ac; in the second case, (when n is greater than $\frac{1}{3}$), if we take mk=3mh the pressure will be nil beyond a_1c_1 and will go on increasing from a, c, to bd.

Note.—It will be seen that the above formulæ are really identical in value with those quoted at the commencement of this article, though under a different form. To establish their identity, it is only necessary to replace N, S and n by their equivalents P, l and $\frac{l-2n}{l}$ (bd)

being supposed to be equal to unity, S=l). But a simple demonstration may be given of the preceding formulæ.

Let us represent the length of the rectangle by 2a; by p and P the pressures at m and n (Fig. 2), and let x be the dis-



tance separating m from any given point in the axis mn, and c the distance between the point h of application and the center o of the axis.

Under the influence of the pressure N, the base mn is more or less displaced (or We assume that it does compressed). not become distorted but remains a straight line. We assume, moreover,and this is in accordance with the laws of elasticity—that at any given point the elementary pressure is measured by the degree of displacement or compression. Thus at m the pressure is measured by mp.

In virtue of these hypotheses, which

calculate the compression by imposing the condition that all the elementary pressures have a resultant equal and opposite to N. For this it is necessary:

1° That the sum of the elementary forces such as mp,—a sum represented by the area of the trapezoid mnpP,—should be equal to N. This furnishes the equation :-

(1)
$$N = (P + p)a$$

2° That the sum of the moments of the elementary forces about the point h should be algebraically equal to o. (Fig. 2).

The sum of the moments of the forces to the left of h is equal to the moment of the area of the trapezoid mhpl, and that of those to the right of h, is equal to the moment of the area of the trapezoid nhPl. The vertical hl is equal to

$$p + (P-p)\frac{a+c}{2a}$$

Note.— $Put \ hl = p + z$. Then z is given by the proportion

$$\frac{z}{\mathbf{P}\!-\!p}\!=\!\!\frac{a+c}{2a}\!;\,z\!=\!(\mathbf{P}\!-\!p)\frac{a+c}{2a}\ and\ hl$$

is found to be as above.

The altitude of the left hand trapezoid is (a+c), and that of the right hand trapezoid is (a-c). Putting the moments of the two trapezoids in equation, we ob-

(2)
$$p.\frac{a+c}{2}.2.\frac{a+c}{3} + \left(p+(P-p)\frac{a+c}{2a}\right) \times \frac{a+c}{2}.\frac{a+c}{3} =$$

$$= \mathbf{P} \cdot \frac{a-c}{2} \cdot 2 \cdot \frac{a-c}{3} + \left(p + (\mathbf{P} - p) \cdot \frac{a+c}{2a} \right) \times \frac{a-c}{2} \cdot \frac{a-c}{2}$$

Note.—It will be observed that the two trapezoids are divided into four triangles by the lines ph, ln and it is the sum of the moments of these triangles which is given in (2).

From equations (1) and (2) the following values of p and P are derived, in terms

(3)
$$P = N \frac{(a+3c)}{2a^2}; p = N \frac{(a-3c)}{2a^2}$$

Note.—To obtain these equations, put experience in a measure confirms, we may A = (a+c) and B = (a-c). Then by reduction, simplification and substituting the value of $P = \frac{N-ap}{a}$ from (1) we have; $2a (3A^2a - A^2 + aB^2 + AB^2) p =$

$$2a (3A^2a - A^3 + aB^2 + AB^2) p =$$

= N $(4aB^2 + AB^2 - A^3)$

Replacing A and B by their values, effecting the necessary calculations and reducing, we have $p=N\frac{(a-3c)}{2a^2}$ as above.

The value of P is then obtained by substitution in (1).

From (3) we see that the maximum pressure occurs at the edge of the rectangle nearest to the point of application of the pressure N.

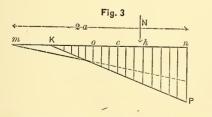
Since the above calculations refer to a rectangle abcd of which the width bd is supposed to be unity, we have S=2a. If now we put $\frac{c}{a}=n$ the value of P may be written under the more simple form given

by Mons. Bresse; $P = \frac{N}{S} (1 + 3n)$

Let us now see how the elementary pressures vary as the force N changes its point of application; c may vary from o to a

For c=o, we have $P=p=\frac{N}{S}$. That is, the pressure is uniformly distributed over the whole base.

As c increases, P also increases, and p diminishes. When $c=\frac{a}{3}$, p=o; so that for $c>\frac{1}{3}$ a there is an area mk (Fig. 3) of the



rectangle which sustains no pressure, and this area is easy to determine, for it is only necessary to take nk=3nh. At k the pressure is nil, as it is also for all the surface situated to the left of k; and the pressure increases progressively from k to n, where it becomes maximum.

For
$$c = \frac{a}{3}$$
; $P = 2\frac{N}{S}$

that is, the pressure is double that which occurs under an uniform distribution.

For
$$c > \frac{a}{3}$$
, we have (Fig. 3) $nk = 3$ $(a-c)$

and the area of the triangle knP which represents the sum of the elementary pressures, should be equal to N, whence we have the relation:

$$N = \frac{P}{2} . 3 (a-c), \text{ or } P = \frac{2}{3} \frac{N}{(a-c)}$$

Put $\frac{c}{a} = n$, and remembering that the surface of the rectangle forming the base is measured by 2a, we may write the value of P thus:

$$P = \frac{2}{3a} \cdot \frac{N}{1-n} = \frac{4N}{S} \frac{1}{3(-n)}$$

When the force N is applied directly at the edge, that is when c=a, the pressure at this point becomes infinite.

The above constitutes the investigation of Mons. Debauve. Before offering any comments upon it, I will add some observations which he makes upon the resistance to crushing of stone, so excellent and practical that they cannot but prove of interest to engineers.

After giving the usual tables of the strength of different varieties of stone, Mons. Debauve says:—

But too much confidence must not be placed in the above figures, for they take no account of a very important factor and one as yet but little studied, namely the influence of the *size* of the specimens tested upon their resistance.

Dupuit in his treatise upon bridges, gives the following results, based, it is true, more upon reasoning than actual experiment:

It has been found, he says, that with equal surfaces, the resistance increases as the section approaches a circle, and that it decreases with the height, particularly if the specimen be divided into several layers. We can easily understand that when several prisms bear upon one another, the pressure is unlikely to be transmitted uniformly over the whole surface. It may happen, therefore, that some parts will be strained beyond their resistance before a pressure is reached

which, if uniformly distributed, could have

been safely sustained.

While upon this subject we will remark, that so far experiments have only been made with uniform pressures extending over the whole surface of the prisms tested. In actual practice however, it often happens that only a portion of the surface sustains pressure. In such cases, can we consider the surface pressed as being isolated, and as liable to be crushed by a pressure that would crush it if it were isolated? We do not think so, although it is customary to so consider it. As we have already stated, crushing only takes place as an effect of lateral dilatation, and when there exists an obstacle to such dilatation, the resistance to crushing is thereby increased. This is a principle well understood in practice. Thus, we ring the head of piles to prevent their splitting, and put iron bands around certain supports destined to bear heavy loads. Let us suppose for instance that a cube of stone five centimetres high crushes under a load of 10,000 kilos, or 400 kilos per square centimetre. We certainly should not conclude from that fact that crushing would ensue if we placed an iron column with a base of 25 square centimetres, in the middle of a block of the same stone, a square metre in area, and loaded it with a weight of 10,000 kilos. It is quite certain that we should find the resistance enormously increased.

The proposition that, under all circumstances, whenever the pressure reaches the limit of resistance crushing ensues, Thus, if leads to absurd consequences. we should calculate the area of the point of a well sharpened pointing tool, we would conclude that it would pass through granite like a needle through a piece of cloth, and that stone could be cut with a razor. The figures we have given (referring to table) only relate to pressures covering the whole surface of the specimen tested. If the pressure is local and only bearing upon certain points, the resistance increases in proportion as these points are farther from the sides, but we know nothing of the manner in which the resistance acts under these circumstances, and for lack of data follow incorrect as-

Instead of multiplying experiments upon all the known stones used in building,

sumptions.

resistance varies with the dimensions of the specimens tested, the pressure being uniformly applied; and secondly, how it varies under local pressures, applied to

different parts of the surface.

Crushing is due, as Dupuit remarks, to the lateral expansion of the stone, the compressed parts endeavoring to escape at the sides, where they find no impediment to so doing. When the pressure becomes so great as to destroy the cohesion of the fibers, they burst asunder, and crushing ensues.

Any cause which opposes this lateral expansion will have for effect the retardation of the crushing of the material, by annulling more or less of the tendency to Mons. Pelletreau in a recent spread. paper corroborates the above statement by demonstrating the following propo-

Other things being equal, a prism of stone resists crushing in proportion to the degree of friction existing between its base and the surface upon which it stands.

In another part of his volume, Mons. Debauve gives instances of very heavy pressures sustained by the pillars of some noted buildings. Thus:

The pillars of dome of the Pantheon. 414 The pillars of tower of St. Méry...... 414 The pillars of Church of Toussaint at An-

These are certainly enormous charges, much greater some of them, than any builder would knowingly incur at the present day. No doubt the architects of these edifices never gave the question of crushing a thought, but simply carried up their structures according to artistic design, and let the pressures be what they Mons. Debauve does not state whether the above pressures occur at the bottom of the foundations, under ground, or in free air. This would unquestionably make a great difference. I do not know what the elementary pressure upon the piers of the Brooklyn bridge is, but it must be something enormous.

It should be remembered too, that the sub-foundations of this structure consist of a heavy layer of timber, resting upon concrete, so the whole of the great weight rests on wood instead of stone. No doubt we should endeavor, first to ascertain how when the substructure is carried down to

such a great distance below the surface, the strong hold which the encasing material takes of its sides very materially lessens the weight actually resting on the bottom. Unquestionably pressures may be admitted below the surface, which would be dangerous if sustained by portions of the structure deprived of lateral support; besides it is certain that at great depths below the surface, the nominal pressures do not really exist, the weight being largely sustained by the adherence on the sides. For this reason, the sides of buried foundations should be built vertical, and not spreading out below ground.

Let us now return to Debauve's exam-

ination of Bresse's formulæ.

It would no doubt be unwise to attempt a thorough investigation of the problem without a careful study of Mons. Bresse's own solution of the given problem by the method of centers of percussion. I have not been able to find this latter author's work in the Astor library, and am therefore ignorant of his process of demonstration, but, as stated at the commencement of this article, his results have been generally accepted, and pass current among the most eminent European authorities without challenge. This is saying a great

As regards Debauve's demonstration, if we admit his assumptions, the results follow naturally. Let us see what these assumptions are. He assumes (as does Bresse) a homogeneous mass. That is a mass, all the parts of which are uniformly bound together, so that any local pressure is disseminated throughout the mass. Thus, a local pressure acting vertically downward, does not bear wholly upon that portion of the base directly under it, but is transmitted to the other parts of the base as well. There can be no difficulty in accepting this assumption, for it is not a scientific abstraction, but a practical essential of good workmanship.

His next assumption is, that the base, while undergoing compression, is not distorted, but remains in a straight line. With this, we must also couple the tacit assumption that the mass rests upon an unyielding base, or one which is practically unyielding. As the structure, in the case of high dams, must stand on bed rock, we cannot refuse to admit this. Even if courses of the work, we should still find, edifice.

I think, that the upward reaction of the rigid base was operative through the in-

tervening material.

The rigidity of the base being admitted, we seem forced to grant the absence of distortion. The only assumption which still remains to be examined is, that compression is proportional to pressure. This can be readily conceded, and it would then appear that Mons. Debauve has rested his demonstration upon reasonable grounds.

It may be remarked that in the problem announced, the sides of the assumed mass are supposed to be vertical. It is difficult to see how this condition affects the results, and it is neglected by Debauve in the application of the formulæ to dams.

It will be observed that he introduces a distance, represented by x, (Fig. 2), of which no use is made in the demonstra-

tion.

One word may perhaps be usefully added upon the subject of compression. All building materials are more or less compressible, and all buildings undergo more or less compression from their own weight and from such exterior forces as they may be subjected to. In the case of masonry this compression takes place mostly in the mortar. But a point is sooner or later reached, when compression ceases, or else the whole structure would flatten out into a sheet of infinite thinness. The mass has then become incompressible. If the pressure still augments, another action takes place, namely, that of crush-We may say that there are three distinct stages in the phenomena accompanying pressure applied to stonework. First, there is the compression due to the artificial and composite character of the mass considered as a whole. This consists in taking up the vacancies of the work, or in the settling of the structure to its bearings. Then comes the condensation, due to the natural compressibility of the materials when brought in actual contact with each other. This is no doubt slight when compared to the former contraction. The pressure still augmenting destruction of the cohesion of the material occurs; that is crushing and disentegra-These three actions may be going on simultaneously in different parts of the same structure; and we may have, according to circumstances, either the establishwe consider the pressure in the upper ment of equilibrium, or destruction of the

BICYCLES AND TRICYCLES.*

By C. V. BOYS.

From the "Journal of the Society of Arts."

The subject of this paper is one of such wide interest, and of such great importance, that it is quite unnecessary for me to make any apology for bringing it before your notice. Exactly two months ago, I had the honor of dealing with the same subject at the Royal Institution. On that occasion I considered main principles only, and avoided anything in which none but riders were likely to take an interest, or which was in any way a matter of dispute. As it may be assumed that the audience here consists largely of riders, and of those who are following those matters of detail, the elaboration, simplification, and perfection of which have brought the art of constructing cycles to its present state of perfection, I purpose treating the subject from a totally different point of view. I do not intend, in general, to describe anything, assuming that the audience is familiar with the construction of the leading types of machines, but rather to consider the pros and cons of the various methods by which manufacturers have striven to attain perfection, As a discussion on the subject of this paper will doubtless follow—and I hope makers or riders of every class of machine will freely express their opinion, for by so doing they will lend an interest which I alone could not hope to awaken-I shall not consider it necessary to assume an absolutely neutral position, which might be expected of me if there were no discussion, but shall explain my own views without reserve.

The great variety of cycles may be grouped under the following heads:—

1. The Bicycle unmodified.

2. The Safety bicycle, a modification of 1.

3. The Center-cycle.

4. The Tricycle, which includes five general types:—

(a.) Rear steerer of any sort.

(b.) Coventry rotary.

(c.) Front steerer of any sort (except e).

(d.) Humber pattern.

(e.) The Oarsman.

5. Double machines: sociables and tandems.

6. The Otto.

It is perfectly obvious that not one machine is superior to all others in every respect, for if that were the case, the rest would rapidly become extinct. Not one shows any signs of becoming extinct, and, therefore, it may be assumed that each one possesses some points in which it is superior to others, the value of which is considered by its riders to far outweigh any points in which it may be The widely varying conditions under which, and purposes for which, machines are used, and the very different degrees of importance which differently constituted minds attach to the peculiarities of various machines will, probably, prevent any from becoming extinct, Nevertheless, the very great advantages which some of these possess over others will, no doubt, in time become evident by the preponderance of the better class of machines.

The bicycle, which surpasses all other machines in simplicity, lightness, and speed, will probably, for these reasons, always remain a favorite with a large class. The fact that it requires only one tract places it at a great advantage with respect to other machines, for it is common for a road which is unpleasant from mud or stones to have a hard smooth edge, a kind of path, where the bicyclist can travel in peace, but which is of little advantage to other machines. Again, the bicycle can be wheeled through narrow gates or doorways, and so kept in places which are inaccessible to tricycles. peculiarity of the bicycle, and to a certain extent of the center-cycle, is that the plane of the machine always lies in the direction of the resultant force, that the machine leans over to an amount depending on the velocity and the sharpness of the curve described. For this reason all lateral strain on the parts is abolished, and if we except the slipping away of the

^{*} A paper read before the Society of Arts.

wheel from under the rider, which can hardly occur on a country road, an upset from taking a curve too quickly is impossible. This leaning to either side by the machine and rider gives rise to that delightful gliding which none but the bicyclist or the skater can experience. In this respect the bicycle has an enormous advantage over any machine, tricycle or Otto, which must at all times remain upright, and which must, therefore, at a high speed be taken round a curve with discretion.

The perfect and instantaneous steering of the bicycle, combined with its narrowness, counteract, to a great extent, the advantage which the tricyclist has of being able to stop so much more quickly, for the bicyclist can "dodge" past a thing for which the rider of the three wheeler must pull up. In one other respect the bicyclist has an advantage, which, though of no real importance, has great weight with many people. The bicycle well ridden presents a picture of such perfect elegance that no one on anything else need expect to appear to advantage in comparison.

The chief disadvantage of the bicycle is the fact that a rider cannot stop for any purpose, or go back a little, without dismounting. For town riding, where a stoppage is frequently necessitated by the traffic, this perpetual mounting and dismounting is not only tiresome but wearying, so much so, that few bicyclists

care to ride daily in town.

The position of the rider on a bicycle with respect to the treadles is by no means good, for if he is placed sufficiently forward to be able to employ his weight to advantage without bending himself double, he will be in so critical a position that a mere touch will send him over the handles. He has, therefore, to balance stability and safety against comfort and power; the more forward he is, the more furiously he can drive his machine, and the less does he suffer from friction and the shaking of the little wheel; the more backward he is, the less is he likely to come to grief riding down hill, or over unseen stones. The bicyclist is no better off than the rider of any The little wheel as a mud-throwing not think bicyclists find them compete in

engine is still more effective on the bicycle than it is on any tricycle, for in general it is run at a higher speed.

I now come to the usual complaint about the bicycle. There is a fashion just now to call it dangerous, and the tricycle safe. But the difference in safety has been much exaggerated. The bicyclist is more likely to suffer from striking a stone than his friend on three wheels. but then he should not strike one where the tricyclist would strike a dozen. Properly ridden, neither class of machine can be considered dangerous; an accident should never happen except it be due to the action of others. People, carts, cattle, and dogs on the road are liable to such unexpected movements, that the real danger of the cyclist comes from the outside; to danger from absolute collapse due to a hidden flaw in the materials employed, every one is liable, but the bicyclist more remotely than the tricyclist, owing to the greater simplicity of his machine. The bicyclist, though he has farther to fall in case of an accident from any of these causes, is in a better position than the tricyclist, for he is outside instead of inside of his machine; he can in an instant get clear. It would appear that many tricyclists consider accidents of the kind next to impossible, for in several machines the rider is so involved, that an instantaneous dismount without a moment's notice, at any speed, is absolutely impossible. There remains one objection, which, however, should be of next to no importance—the difficulty of learning the bicycle prevents many from taking to the light and fast machine, because they are afraid of a little preliminary trouble.

The chief objections to the bicycle, then, are the liability of the rider to go over the handles, the impossibility of stopping very quickly, and the inability to remain at rest or go backwards, and

the difficulty of learning.

The first two of these are, to a large extent, overcome in the safety bicycles, but not without the introduction of what is in comparison a certain degree of complication, or without the loss of the whole of the grace or elegance of the bicycle. other machine with a little wheel, the On almost all these safety bicycles the vibration from which may weary him rider is better placed than on the unnearly as much as the work he does. modified bicycle, but though safer I do speed, though, no doubt, they are superior in that respect to the tricycle. Though they do not allow the rider to stop without dismounting, the fatigue resulting from this cause is less than it is with a bicycle, owing to the fact that with the small machines the rider has so small a distance to climb. Of these machines, the "Extraordinary" leaves the rider high up in the air on a full-sized wheel, but places him further back and more over the pedals. The motion of these is peculiar, being not circular but oval, a form which has certain advantages.

In the Sun and Planet and Kangaroo bicycles, a small wheel is "geared up," that is, is made to turn faster than the pedals, so as to avoid the very rapid pedaling which is necessary to obtain an ordinary amount of speed out of a small wheel. In each of these the pedals move in a circular path, and their appearance is in consequence less peculiar than that of the Facile, which, in this respect, does not compare favorably with any good machine. The pedal motion on the Facile is merely reciprocating. Riders of machines where circular motion is employed, among them myself, do not believe that this reciprocating motion can be so good as circular, but I understand this view is not held by those who are Of course, the harmonic used to it. motion of the Facile pedal is superior to the equable reciprocating motion employed in some machines where speed is an object, especially with small wheels.

If I have overlooked anything typical in the modified bicycle class, I hope some one will afterwards supply the omission, and point out any peculiarities or advan-

tages.

That very peculiar machine, the Centercycle seems to combine many of the advantages of the bicycle and tricycle. On it the rider can remain at rest, or can move backwards; he can travel at any speed around curves without an upset being possible; he can ride over brickeven touching them. As this machine is very little known, a few words of explanation may be interesting.

over the main wheel, as in the bicycle, but wheel only need be turned. If the axes much farther forward. There are around of no two are common, then the planes of him, on or near the ground, four little two of the wheels must be turned in

wheels, two before and two behind, supported in a manner the ingenuity of which calls for the utmost admiration. Turning the steering handle not only causes the front and rear pairs to turn opposite ways, but owing to their swivelling about an inward pointing axis, the machine is compelled to lean over towards the inside of the curve: not only is this the case, but each pair rises and falls with every inequality of the road, if the rider chooses that they run on the ground: but he can, if he pleases, arrange that in general they ride in the air, any one touching at such times as are necessary to keep him on the top of the one wheel on which alone he is practically riding. He can, if he likes, at any time, lift the main-weeel off the ground, and run-along on the others only. The very few machines of the kind which I have seen have been provided with foot straps, to enable the rider to pull as well as push, which is a great advantage when climbing a hill, but this is on every machine except the Otto, of which I shall speak later, considered a dangerous practice.

Some of the objections to the bicycle to which I have referred were sufficient to prevent many, especially elderly men, from dreaming of becoming cyclists. long as the tricycle was a crude and clumsy machine, there was no chance of cycling becoming a part, as it almost is, and certainly soon will be, of our national The tricycle has been brought to such a state of perfection, that it is difficult to imagine where further progress

can be made.

Perhaps it will be well to mention what is necessary, in order that a threewheeled machine may be made to roll freely in a straight line, and also round curves. At all times each wheel must be able to travel in its own plane in spite of the united action of the other two. run straight, the axes of all the wheels To run must obviously be parallel. round a curve, the axis of each must, if bats, or obstructions, not only without continued, pass through the centre of being upset, but if going slowly, without curvature of the curve. If two wheels have a common axis, the intersection of the two lines forming the axis can only meet in one point. To steer such a com-In the first place, the rider is placed bination, therefore, the plane of the third

Not only does free rolling depend on the suitable direction of the planes of the wheels, each wheel must be able to run at a speed proportional to its distance from the point of intersection of the center of curvature.

The most obvious way, then, of contriving a three-wheeler is to drive one wheel, steer with another, and leave the third, which must be opposite the driver, idle. The next in simplicity is to drive with one wheel, and steer with the other two, having one in front, and the other behind. So far, then, the single driving rear-steerer and the Coventry rotary pattern are easily understood. The evils of single driving minimised, it is true, to a large extent in the Coventry rotary, have led to the contrivance of means by which a wheel on each side may be driven without interfering with their differential motion in turning a corner. Three methods are commonly used, but as only two are employed on tricycles, I shall leave the third till I come to the special machine for which it is necessary. The most easy to understand is the clutch, a model of which I have on the table. If each main wheel is driven by means of one of these, though compelled to go forward by the crankshaft, it is yet free to go faster without restraint. By this means "double driving" is effected in several forms of tricycle. Differential gear, which is well understood, and of which there are several mechanically-equivalent forms, divides the applied driving power, whether forwards or backwards, between the main wheels, equally if the gear is perfect, unequally if imperfect. To understand the effect of the two systems of driving, and of single driving, let us place on grooves a block which offers resistance to a moving force. If we wish to move it, and apply our force at the end of one side, it will tend to turn round as well as move forward, and much friction will be spent am unduly thrusting myself forward, if I on the guides by their keeping it straight. refer to a scheme of my own, in which no This is the single driver. If, instead of toothed wheels are employed, but in applying force at one side, we push the which two conical surfaces are driven by block bodily forward by a beam moving a series of balls lying in the groove beparallel to itself, then so long as the guides are straight no strain will be put upon them, even though one side of the wooden diagrammatic model, and a small

order that the three axes may meet in a however, the guides compelled the block to travel round a curve, then the power, instead of being divided between the two sides in such proportion as is necessary to relieve the guides of all strain, is suddenly applied only to the inside, and the effect is that of a single driver only. This three axes, i. e., from the ever-shifting is the clutch. Lastly, if the last-mentioned beam, instead of being pushed along parallel to itself, were pivoted in the middle, and that pivot only pushed, the same power would be applied to each side of the block, and no strain would be thrown on the guides, whether straight or curved, so long as the resistance opposed to the block on the two sides were equal; if, however, one side met with more resistance than the other, then the guides would have to keep the block straight. This is the differential gear. I have assumed that in the last case the force was applied to the middle of the beam; this corresponds to every evenlybalanced gear. In the gear employed by Singer, which is not evenly balanced, but which derives its good qualities from its simplicity, the same effect is produced as if the beam were pivoted on one side of the center, instead of on the center. Thus, though both sides are driven, one is driven more than the other. On the whole, there is no doubt that the balanced gear gives a superior action to the clutch, for except when the two sides of the machine meet with very different resistance, and then only when running straight, the clutch will not compare with the other. The clutch also gives rise to what is considered by most riders a grave defect, the inability to back treadle, while the free pedal, which is an immediate consequence, is considered by others a luxury. On the other hand, this same free pedal can be obtained on differentially-driven machines to which speed and power gear have been applied.

Of the relative merits of different forms of differential gear there is little to be said. Perhaps it will not be thought I block is resisted more than the other; if, working model in steel, which shows that

the new principle employed is correct, namely, that a ball while jambed is free to turn, or if turning is able to jamb. All Humbers, and most front steerers, employ differential gearing; in some front steerers the clutch of necessity is used.

Neglecting for the present the different modes of transmitting power from the pedals to the main wheels, it is possible now to consider the four typical builds of tricycle. The only advantage that a rider can find in a rear-steerer is the open front, so that in case of accident he can more easily clear himself of his machine; as I have already remarked, this power of instantly escaping seems to be considered by many as of no importance. In a rearsteerer which has not an open front, whether driven by a clutch or by differential gear, I fail to discover any good quality. The steering of a rear-steerer is so very uncertain, that such machines cannot safely be driven at anything like a high speed, because any wheel meeting with an obstruction will, by checking the machine, diminish the weight on the steering wheel just at the time when a greater weight than usual should be applied. It is for the corresponding reason that the steering of a front-steerer is so excellent; the more the machine is checked by obstruction, by back treading or by the brake, the greater is the weight on the front wheel. For shooting hills, or for pulling up suddenly, no machine of any kind will compare with a good front-steerer. In all respects it is superior to the rear steerer, if we except the open front, but against this may be set the fact that on many the rider can mount from behind, or can dismount in the same manner while the machine is in motion. Experience shows that the frontsteerer is, for general excellence, safety, easy management, and light running, the best all-round tricycle that is to be had.

The Humber build, which departs less from the ordinary bicycle than any other, is far superior to all others for speed; it is, however, somewhat difficult to manage, for the steering is not only delicate, but critical, requiring constant care lest a stone or other obstruction should take the rider unawares, and steer the machine for him. The control which a skillful rider of the Humber has over his mamachine among tricycles is unequaled. travel faster than the treadles, and so be

So great a favorite is this form, especially among the better class of riders, that almost every firm have brought out their own Humber, each with a distinguishing name. The only improvement or change, whichever it may be, that has been made by others with which I am acquainted, is the triple steering, in which the hind wheel moves the opposite way to the others. The corresponding change in the bicycle was soon discarded; I do not know what advantage can result from the increased delicacy of steering here; I should have thought it delicate enough already.

One noticeable change in the frontsteering tricycle, which has been largely made lately, is the substitution of central for side-gearing, in consequence of which bicycle cranks can be employed, instead of the cranked axle, with its fixed throw. This gives an appearance of lightness which the older types of machine do not possess.

I now come to that very difficult and all-important subject, the method of transmitting power from the body of the rider to the main axle. Next to the structural arrangement, this is most important in distinguishing one type of machine from another.

The first to which I shall refer is the direct action employed on the "National" and the "Monarch" tricycles. It is obvious that by having no separate crank shaft, much greater simplicity and cheapness, and less friction are attained, than can be possible when the extra bearings and gear generally used are employed. In this respect the direct action machines undoubtedly have an advantage, but an advantage of any kind may be too dearly bought, as it certainly is here. In the first place, the direct action can only be applied to a rear-steering, clutch-driven machine, or single driver, for if the wheels were not free to run ahead, it would be impossible to go round a curve. In the second place, the rider must be placed at such a height for his feet to work on the axle, that the machine of necessity is very unstable, and is likely to upset if ridden without great caution round a curve. Thirdly, to diminish as far as possible this last objection, miserable little wheels must be employed, which chine is wonderful; the elegance of the cannot be geared up, that is, made to

equivalent to larger wheels. Therefore, though it is likely that at such low speeds only as it is safe to run such a machine, it may move more easily than a machine of a recognized type, and though direct action would undoubtedly be advantageous if it did not entail defects of a most serious order of magnitude, we may dismiss this at once from our consideration. It is true that in the "Monarch" a few inches of height are gained by the hanging pedals, but I question very much whether one machine is much better than the other.

The chain which is used on almost every make of machine cannot be considered perfect; it is, on the whole, a dirty and noisy contrivance, giving rise to friction where the links take and leave the teeth of the pullies; stretching, or rather lengthening, by wear, and, finally, allowing back lash, which is most unpleasant. In spite of all this it affords a convenient and reliable means of transmitting power, which is applicable to every type of tricycle except one.

Instead of a chain, an intermediate or idle wheel has been tried, but this has not been found advantageous. The intermediate wheel has been removed, and the crank and wheel pulley allowed to gear directly together, making reverse motion of the feet necessary, and possi-

bly reducing friction.

The crank and connecting rod are employed in some machines. If there are two only, they must not be placed in opposite positions, but be fixed at an angle, so that there are times when each rod is under compression, a strain which delicate rods cannot stand. In the threethrow crank, employed in the matchless tricycle, this objection is obviated, for one, at least, is at all times in such a position as to be in tension. The objection to the crank is the fact that it weakens the shaft, and that it can only be used with a clutch, not with a differential

driver, the one of which the working friction is least, is the endless steel band, so ably fearing lest it should slip. The Otto shows that it can safely be employed.

now show a model, which seems to me. to be free from the objections which may be urged against other methods; but I, of course, cannot be considered in this respect. a judge. Eccentrics are well known as equivalent to cranks, but if used in the same way, with a connecting rod, either fatal friction or enormous ball-bearings would be necessary. Instead of these, I connect two pair of equal eccentrics by an endless band embracing each, so that the band acts like a connecting rod without friction, and at the same time acts by its turning power as on the Otto, thus making two eccentrics sufficient instead of three, and carrying them over the dead points.

There is one more system of transmitting power employed on a few machines. In these a band or line passes over the circumference of a sector or wheel, and the power is directly applied to it. The motion of the feet in the omnicycle, and of the hands and body in the oarsman, is therefore uniform. There would be no harm in this if it were not for the starting and the stopping, which cannot be gradual and at the same time effective in machines of this type. For this reason a high speed cannot be obtained; nevertheless, these machines are better able to climb hills than are tricycles with the usual rotary motion, for, at all parts of the stroke—which may be of any length that the rider chooses—his driving power on the wheels is equal. The ingenious expanding drums on the omnicycle makes this machine exceptionally good in this respect, for increased leverage is effected without increased friction, which is the result of "putting on the power" in some of the two-speed contrivances.

Having spoken of the oarsman tricvele, I must express regret that I have not been able to find an opportunity to ride on or with the machine, so that I cannot, from observation, form an opinion of its going qualities. There can be no doubt that the enormous amount of work that can The most silent, neatest, and cleanest be got from the body in each stroke on a sliding seat in a boat must, applied in the same manner on the oarsman tricycle, well known in connection with the Otto make it shoot away in a surprising bicycle. This is not, as far as I am aware, manner; whether such motion, when conemployed on any tricycle, makers problimed for hours, is more tiring than the ordinary leg motion only, I cannot say for certain, but I should imagine that it I have devised a scheme, of which I would be. The method by which the

steering is effected by the feet, and can with one foot be locked to a rigidly straight course, is especially to be admired.

There is much difference of opinion with respect to the most suitable size for the wheels of machines. Except with certain machines, this has nothing to do with the speed at which the machine will travel at a given rate of pedalling, for the wheels may be geared up or down to any extent that is made to turn more quickly or slowly than the cranks. This, the most suitable speeding, is a separate question, and must be treated by itself.

Large wheels are far superior to small wheels in allowing comfortable easy motion, a matter of considerable importance in a long journey. They are also far better than small for running over loose or muddy ground, for, with a given weight upon them, they sink in less, from the longer bearing they present, and this, combined with their less curvature, makes the everlasting ascent which the mud presents to them far less than with a smaller wheel. On the other hand, the large wheel is heavier, and suffers more from air resistance than the small wheel. For racing purposes a little wheel, geared up of course, is certainly better than a high wheel; for comfortable traveling, already one little wheel. steering wheel. doubt results.

sequel to high and low wheels. Of course, obtain so great an advantage in climbing gearing, from which the epicyclic contri-

hills as might be expected. To make such a machine travel at a moderate speed only, excessively rapid pedalling is necessary, and the rider is made tired more by the motion of his legs than by any work he is doing. The slow, steady stroke by which a rider propels a highgeared machine is far more graceful and less wearying than the furious motion which is necessary on a low-geared ma-The height up to which the driving wheels are usually geared may be taken as an indication of the ease with which any class of machines runs. rider on a low-geared machine can start his machine much more quickly than an equal man on one that has high gearing, and therefore in a race he has an advantage at first, which he speedily loses as his rapid pedalling begins to tell. For ordinary riding, the slight loss of time at starting is a matter of no importance whatever.

There are several devices which enable us to obtain the advantages of high and low gearing on the same machine, which at the same time give the rider the benefit of a free pedal whenever he wishes. On some single driving rear-steering tricycles the connection on one side is for speed, and that on the other for power, either being in action at the wish of the and in general, the high wheel is prefer-rider, or both speed and power combina-Though this is certainly the case, tions are applied on the same side. To it does not follow that large wheels are drive with a power gear a single wheel worth having on a machine when there is only seems to me the height of If the rider is folly; in my opinion no arrangement of to be worried with the evils of a little this type is worthy of serious attention. wheel at all, it is possible that any ad-Among the better class of machines there vantage which large wheels would give are three methods by which this change him would be swamped by the vibration is effected—First, that employed on the and mud-sticking properties of the small omnicycle, to which I have already re-One firm, in their en- ferred; secondly, an epicyclic combinadeavors to minimize these evils, have de-tion of wheelwork which moves as one signed machines without any very small piece when set for speed, thus adding wheels; all three wheels are large, and a nothing to the working friction except steadier and more comfortable motion no by its weight, but which works internally when set for power, thus reducing to a High and low gearing are the natural small extent, by the additional friction, the gain of power which the rider desires; the lower the gearing the greater is the thirdly, a double set of chains and pulmechanical advantage in favor of the rider leys, each set always in movement, so when meeting with much resistance, that whether set for speed or power, whether from wind, mud, or steepness of there is rather more friction than there slope. In spite of this, for some reason would be if there were no additional which I cannot divine, the machines chains, but these are free from that inwith excessively low gear do not seem to creased friction due to toothed-wheel

vances suffer only when set for power. There is much difference of opinion whether any of these arrangements are worth carrying, for perhaps nine miles, for the sake of any advantage that may be obtained in the tenth. It is on this account that the drums on the omnicycle are so excellent; whether expanded or not, there is, on their account, no loss of work whatever, for there is no additional friction. The subject of these two speed gears will, I hope, be discussed; it is one which, though not new, is coming more to the front, and about which much may be said.

Having now dealt with the means by which tricycles are made to climb hills more easily, I wish to leave the subject of bicycles and tricycles altogether for a few minutes, to say a few words which may specially interest those who are fond of trying their power in riding up our best known hills. The difficulty of getting up depends to a large extent on the surface and on the wind, but chiefly on the steepness. The vague manner in which one hill is compared with another, and the wild ideas that many hold who have not made any measurements, induces me to describe a method which I have found specially applicable for the measurement of the steepness of any hill on which a cyclist may find himself, and also a scheme for the complete representation of the steepness and elevation of every part of a hill on a map so as to be taken in at a glance. The force required to move the thing up a slope is directly proportional, not to the angle, but to the trigonometrical sine of that angle. To measure this, place the tricycle, or Otto—a bicycle will not stand square to the road, and therefore cannot be used—pointing in direction at right angles to the slope of the hill, so that it will not tend to move. Clip on the top of the wheel a level, and mark that part of the road which is in the line of sight. Take a string made up of pieces alternately black and white, each exactly as long as the wheel is high, and stretch it between the mark and the top of the wheel. If there are n pieces of string included, the slope is 1 in n, for by similar triangles the diameter of the wheel is to the length of the string as the vertical rise is to the distance on the road.

piece sufficiently long to be worth testing, because an incline, only a few feet in length, of almost any steepness can be mounted by the aid of momentum.

There is only one process with which I am acquainted which supplies a method of representing on a map the steepness of a road at every part. Contours, of coures, show how far one has to go to rise 50 or 100 feet, but as to whether the ascent is made uniformly or in an irregular manner with steep and level places, they tell us nothing. Let the course of a road be indicated by a single line where it is level, and by a pair of lines where in-Let the distance between the lines be everywhere proportional to the steepness, then the greatest width will show places of intermediate steepness, the crossing of the lines, which must be distinguishable from one another, will show where the direction of the slope changes. Further, the size of the figure bounded by the two lines will show the total rise; a great height being reached only by great steepness or by great length, a large figure being formed only by great width or by great length. Those who are mathematically inclined will recognize here that I have differentiated the curve representing the slope of the hill, and laid the differential curve down in plan.

Having wandered off my subject, I must return to more mechanical things, and give the results of some experiments which I have made on the balls of ball bearings. There is no necessity to argue the case of ball v. plain bearings, the balls have so clearly won their case, that it would be waste of time to show why. Of the wear of the twelve balls forming one set belonging to the bearings of the wheels of my Otto, I have on a previous occasion spoken; I may, however, repeat that in running 1,000 miles, the twelve

balls lost in weight only $\frac{1}{20.8}$ grain, or each ball lost only $\frac{1}{250}$ grain. The wear of the surface amounted to only $\frac{1}{1550000}$ inch; at the same rate of wear, the loss

in traveling from here to the moon would amount to only $\frac{1}{3\pm .3}$ of their weight.

to the length of the string as the vertical examined each ball every 200 miles, and cal rise is to the distance on the road. was surprised to find that on the whole This gives the average steepness of a the wear of each, during each journey

varied very little. The balls experimented on were a new set obtained from Mr. Bown. I also had from him one ball of each of the following sizes 3, 4, 5, 6, and 7-16ths of an inch in diameter, as I was curious to know what weight they would support without crushing. As a preliminary experiment, I placed a spare 5 ball between the crushing faces of the new testing machine at South Kensington, and applied a gradually increasing force up to 7 tons 91 cwt., at which it showed no signs of distress. On removing it I found that it had buried itself over an angle of about 60° in the hard faces, faces so hard that a file would not touch them. Those marks will be a permanent record of the stuff of which the ball was made. The ball itself is sealed in a tube, so that any one who is curious to see it can do so. Finding that the crushing faces were not sufficiently hard, I made two anvils of the best tool steel, and very carefully hardened them. These, though they were impressed slightly, were sufficiently good for the purpose. In the following Table are the results of the crushing experiments:-

3 ball at 2 tons 13 cwt. did not break, but crushed on removing part of the weight.

1/4 ball at 3 tons 15 cwt. did not break, but crushed on removing part of the weight.

⁵/₁₆ ball at 4 tons 9 cwt. broke.

3 ball at 8 tons 6 cwt. did not break, crushed under another 120 pounds.

⁷/₁₈ ball crushed before 3 tons, with which I was starting, had been applied. Examination showed that the steel bar of which it was made had been laminated.

These experiments do not tell much of importance; they are curious, and, perhaps, of sufficient interest to bring before your notice. The fragments are all preserved in tubes, and labeled so that anvone who likes to see them can do so.

Of the advantage which a machine which will collapse or fold up when desired, but retain its form on the road, offers in convenience, it is unnecessary

for me to speak.

Of double machines, the Rucker tandem bicycle seems to me to be in every speak only from imagination and not from port of the front-steering Humber. The independent steering, experience.

with its mud-throwing and vibrating tendencies, combine to make a machine which ought to be superior in almost every desirable quality to any other; what it may be in practice I hope to hear in the discussion.

Of double tricycles, the Sociable has been tried by many, and is practically a failure in so far as traveling quickly and easily is concerned. The Tandem, though it presents so objectionable an appearance, seems likely to become a favorite, for it surpasses any single tricycle, and rivals the bicycle in speed. How it may compare in comfort or in safety with the single machine, perhaps those few who are well acquainted with them will say; at any rate, in the case of the Humber, greater stability is given to the steering owing to the weight of the front rider.

Time will not allow me to say more of these machines, or to attack the subject of steam, electric, or magic tricycles, which I had hoped to do. With steam and electricity we are well acquainted; by magic tricycles, I mean those driven by a motor which, without any expense, will drive one twenty miles an hour, up or down hill, with perfect safety. Highway regulations, and certain reasons not well understood, have at present prevented these contrivances from making a revolution.

There remains one machine which must be considered separately, for it cannot be classed with any other. This is the Otto bicycle. My opinion of this machine is so pronounced that I do not care to state it fully. I shall merely give the reasons why I prefer it to anything else, and in so doing I shall be taking the first step in the discussion, in which it will be interesting to hear from riders of other machines the reasons for their preference.

In the first place, the evils of a third or little wheel, the cause of trouble in all tricycles, are avoided. There is none of the vibration which makes all other machines almost unbearable to Ottoists, vibration which tricyclists have learned to consider a necessary accompaniment of cycling, but which has, no doubt, been respect the best, but I should add that I diminished by the use of the spring supwould be presumptuous in me to make the impossibility of capsizing forwards or any remarks on the effect of this vibrasideways, the position of the rider over tion on the human system; we shall all his work, the absence of any little wheel be anxious to hear what our Chairman

has to say on this point. By having only two wheels we have only two tracks, so that we can travel at a fair speed along those places in the country called roads, which consist of alternate lines of ruts and stones, where a three-track machine could not be driven, and where, from the quantity of loose limestone in the ruts, a little wheel of a two-track tricycle would be likely to suffer. By having no little far as the general position taken by the wheel, we can ride in dirty weather without having the rest of our machine pelted with mud, so that cleaning takes less time than it does with anything else. As I have already remarked, the small wheel is the culprit which makes the bicycle and tricycle drive so heavily on a soft road. The ease with which the Otto can therefore be run through the mud, astonishes everyone. Having no little wheel, we can obtain the full advantage of the high 56 inch wheel, which almost everyone prefers. As I have ridden all combinations, from a 50-inch geared up to 60-inch, to a 60-inch geared level, I can speak from experience of the increased comfort to be derived from these large wheels, though for speed only they do not compare with the smaller and lighter wheels geared up. A further point gained by the use of two wheels only is the fact that the whole weight of machine and rider is on the driving-wheel, as it is also on the steering-wheels, so that by no possibility can the wheels be made to slip in the driving, or to fail in steering from want of pressure upon them.

The most important consequence, however, is the absence of any fixed frame. In all machines, bicycles and tricycles, with the usual fixed frame, a position is found for the saddle, which is, on the whole, most suitable. For some particular gradient it will be perfect, on a steeper gradient the treadles will be further in advance, but with a steeper gradient the rider should be more over the front of the treadles. To get his weight further to the front, he has to double up in the middle, and assume a position in which he cannot possibly work to advantage. The swinging frame of the Otto carries a deviation has to be made, the steering that the Ottoist when working at his rider may, if sufficiently confident, travel

strength in a perfectly natural position. On going down a slope, the fixed frame of a bicycle or tricycle leans forward, and places the rider in such a position that extra weight is thrown on his arms and shoulders, whereas the swing frame of the Otto goes back, and the rider of necessity assumes that position in which his arms are relieved of all strain. In so automatic Otto frame is concerned, nearly the same effect can be obtained by using the swing frame of the Devon tricycle, which can be shifted and locked in any position which the rider wishes, or by the sliding saddle which can be slid backwards or forwards and locked so as to place the rider in one of three positions. Though the rider can by these devices assume nearly that position with respect to the treadles which is most advantageous, he cannot obtain that curious fore and aft oscillation made use of by the Ottoist in climbing hills, which, as the model on the table shows, enables him to get past the dead points without even moving, and which, therefore, makes the Otto by far the best hill-climbing machine there is, if account is taken of the high speeding with which all Ottoists ride. This is a proposition which none who knows the machine will question for one moment.

The freedom of motion resulting from the swing of the frame of the Otto gives a pleasurable sensation, which those who have only experienced the constrained motion of a three-wheeler cannot even understand.

The very peculiar method of driving and steering which seems so puzzling to the novice, especially if he is a good rider of other machines—for in that case he is far worse off than one who has never ridden anything—give the rider, when he is familiar with them, a control over the machine which is still surprising to me. the first place, the machine will run along straight, backward, or forwards, so long as the handles are let alone. This automatic straight running is a luxury, for till the treadles, of necessity, further back, so handles need not be touched, and the hardest, is still upright, with his hands in with his arms folded or his hands in his the line between his shoulders, and his pockets. The rigid connection between feet and his arms straight, so that he can the cranks and the wheels does away with hold himself down, and employ his all the back-lash, which is so unpleasant

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with chain or toothed-wheel gearing. the machine possesses the advantage of the clutch over the differential gear when meeting with unequal resistance on a at the same speed; but, in turning a coronly, which is done by the clutch or both wheels equally, which is the case with differential gear, each wheel is driven, but the outer one more than the inner. At high speeds, the steering of the Otto has this advantage, that whereas, with a given action on a tricycle, the same deviation will be effected in the same space at high as at low speeds, the same action on the Otto will, at high speeds, produce the same deviation in the same time as it does at low speeds; and so instead of becoming more sensitive at high speeds, as is the case with the tricycle, the steering of the Otto remains the same. This is because the steering of the tricycle depends on a kinematical, that of the Otto on a dynamatical principle.

In another respect, no machine can approach the Otto; at almost any speed the rider can, if there is reason, instantly dismount, by which action he puts on the brakes, and the machine will save him from falling, stopping with him almost instantly. As is well known, we can move backwards and forwards, we can twist round and round in our own width, or can ride over bricks with impunity.

One objection to the machine is the There is no differential gear or clutch, but difficulty of learning, which is considerable, but which presents no danger. This difficulty has been much exaggerated, for before the present powerful brake was apstraight course, for each wheel must travel plied, it did require considerable skill to ride it down a steep hill. The way to do ner, instead of driving the inner wheel this must still be learnt, but it is now comparatively easy. For going down steep hills, the front-steering tricycle is without a rival; I do not know what other machine will do this better than the Otto. Lastly, the foot straps, which would be a great advantage on any machine, if only they were safe, are not—though none but riders will believe it-in any way a source of danger on the Otto. Having ridden this machine for close upon 10,000 miles, I can speak with more authority on this point than can those who are not able to sit upon it for a moment.

> The only disadvantage which the machine presents is the fact that it is impossible to remove the feet from the pedals while running without dismounting; but though they must at all times follow the pedals, the Ottoist is not, as is generally thought, working when descending a hill.

The enthusiastic terms in which every one who has mastered the peculiarities of the Otto speaks of it would be considered as evidence in its favor, if we were not all considered by other cyclists to be in various stages of lunacy.

THE SEWERAGE AND REFUSE-DISPOSAL OF TOWNS.

BY PROF. VIRCHOW.

From Abstracts of the Institution of Civil Engineers.

At the tenth meeting of the German in tubs, or of their discharge into closed Health Society, the following six theses were submitted by Professor Virchow, of Berlin, with a view to their discussion, but not for formal adoption.

1. Water-cleansing and water-seals are essentially needed for soil-pipes in houses.

2. Long-continued storage of fecal matters, either in middens or cesspools, in boxes or in tubs, must be avoided.

3. Choice may be made, in accordance with local circumstances, either of the direct removal of the excreta from dwellings

channels or drains.

4. The introduction of sewage into public watercourses is in all cases objectionable. In towns having upwards of 100,000 inhabitants, this practice should in no case be permitted. In towns under 100,000 it should only take place where the conditions of current-velocity are especially favorable, and then only when proper precautions are adopted for disinfection and defecation.

5. The introduction, also, into public

watercourses of street and house drainage water, in the case of large and moderate sized towns, should only be permitted after thorough deposition of the sediment, which process may require to be further aided by chemical treatment, in accordance with the quantity and quality of the water which has to be dealt with.

6. The agricultural employment of fecal matters must be subject to strict sanitary supervision; but no more should be expected from sewage grounds, in the vicinity of towns than what has been insisted upon in the case of ordinary agricultural

operations of a like nature.

In dealing with the first proposition, Professor Virchow stated that even Captain Liernur, who had been foremost in asserting the sufficiency in his closets of a seal consisting of urine, had recently abandoned this position, and had admitted the advisability of the use of water. With respect to the second proposition, he pointed out the impossibility of ensuring the necessary sanitary conditions when any system, hitherto introduced, of storing excrement in the vicinity of dwellings was resorted to. Even in the case of tubs the intervals of removal were frequently so lengthy that dangerous de-

composition might arise.

The three following theses are intimately connected, and Dr. Virchow alluded to the difficulty of removing polluting ingredients from water, and stated that he was greatly opposed to the discharge of fecal matters into streams. The selfcleansing powers of rivers, upon which so much reliance has been placed, have, he believes, been much exaggerated. Experiments at the Berlin sewage-farm have proved how rapidly a certain degree of improvement in polluted water may be attained, but they have also demonstrated how long and how far the evil effects of river-pollution may continue. He observed a growing tendency on the part of towns to resist the cost involved in dealing with polluted water; but, to prove its necessity, he stated that towns situated on the sea coast, where the speedy discharge of sewage into the sea would be considered the most ready way out of the difficulty of dealing with this question, were gradually calling for some better plan of disposing of their sewage. He noticed the difficulty of persuading agrinoticed the difficulty of persuading agricharging and discharging are generally more culturists of the value of sewage water, rapid than correspond to these experiments.

and insisted on the need of providing sewage-grounds independent of the surrounding farmers, who will only take the sewage-water when it suits their purpose, and who frequently reject it when the town is most desirous of sending it to them.

With respect to his final proposition, he showed that often enough no difficulty is made when farmers apply excrementitious matters to their land, and which, when washed into streams and rivers by heavy rainfall, may give rise to wholesale pollution, whilst the least discharge of sewage into streams by towns is made the occasion of widespread complaint.

THE ELECTROMOTIVE FORCE OF ACCUMULATIONS—M Revujer, the well-known elec-TORS.—M. Reynier, the well-known electrician, has made experiments on three systems of secondary battery: (1) the Planté accumu-lator of reduced lead, peroxide of lead, and sulphuric acidulated water; (2) the copper accumulator of lead, copper, lead peroxide, acidulated solution of sulphate of copper; (3) the amalgamated zinc accumulator of zinced lead, lead peroxide, acidulated solution. His object was to test the electromotive forces of the combinations and find there variations of sulphate of zinc. The accumulators were not completely formed. The electrometive forces were measured during charge and discharge by the method of equal deflection. His results confirm those formerly obtained by M. Gaston Planté, and are as follows: (1) In the three systems of accumulators studied, the secondary electromotive force is notably more elevated during charge than during discharge. The ratio of the smallest of these values to the greatest may be called the coefficient of fall. It is a factor of loss which effects the efficiency of accumulators. (2) The fugitive super-elevation of the electromotive force augments with the intensity of the charging current and the electromotive of the source. (3) In the Planté accumulator the electromotive force is at least 1.95 volts during the charging and at most 1.85 volts during the discharge. The coefficient of fall is therefore 0.95 under the most favorable conditions. (4) In the copper accumulator the electromotive force is at least 1.43 volts during charging and at most 1.25 volts during discharge. The coefficient of fall is therefore 0.87 under the most favorable conditions. The copper accumulator is that which loses most. (5) In the amalgamated zinc accumulator the electromotive force is at least 2.4 volts during charging and at most 2.36 volts during discharge. The coefficient of fall is during discharge. The coefficient of fa 0.983 in the most favorable conditions. amalgamated zine accumulator is that which loses least. (6) In practice the losses due to variations of electromotive force will be greater than are indicated above, because the times of

THE SYSTEMATIC DIVISION OF LAND—A PRELIMINARY STUDY.

BY HOSEA PAUL.

From the Journal of the Association of Engineering Societies.

considerable extent, is put into the mark- in connection with other parts which are et, a systematic division is not only pos- more desirable. For instance, a rocky sible and practicable, but its advantages are so manifest that in modern times something of the sort is universally attempted with varying degrees of success. It is not difficult to hit upon some system that will be better than the haphazard selection that would proceed in the absence of any plan. It is so easy to accomplish this much that the subject is rarely a matter of thoughtful consideration or intelligent action, what is done being either in haste or left to incompetent hands, which circumstance may perhaps serve as an explanation why there are so few examples in laying out land, either in country or city, where the full capabilities of systematic division are fully brought out.

Systematic division might be defined to be the laying out of land into simple, regular geometrical figures, preferably rectangles of nearly uniform extent, and described by numbers recurring in regular order. It deals not only with the present, but to secure the best results it must in a measure forecast the future and provide for its needs; it must regulate yet not cramp the free play of individual action, by giving grooves and

channels to lessen friction.

Among the advantages to be derived from systematic division might be enumerated:

1. By its providing for present requirements parcels of suitable size ready and convenient for examination and occupancy, without the delays caused by special selection, the consequent bargaining, and the necessity of special sur- it.

2. By its recognizing the possibility of and providing for its future division into

still smaller parcels.

3. Inasmuch as any regular figure will include land of varying worth, there will be a better opportunity of disposing of

When new territory, especially if of those portions of little value separately hillside, unsalable separately, may prove a useful addition to a lowland farm for pasturage, the growth of timber, or because of springs of water. In this way the seller can avoid the accumulation of undesirable remnants.

- 4. A regular division will better accommodate the uses to which land may be put either for the growing of crops, or erecting buildings upon. It aims to provide for "the greatest good of the greatest number."
- 5. Few advantages of regular division are so obvious, so striking and important as the increased ease and greater possibilities in the way of graphic representation.
- 6. This graphic representation is possible at the beginning, often as fully as needed for many purposes without other surveys than those actually made in laying out the divisions.
- 7. The surveys may be mainly shown by maps covering a considerable number of the divisions and the necessary facts of direction and distance noted in the Such maps can be lines themselves. easily copied or published, and convey almost at a glance an amount of information that would otherwise occupy a large and usually widely scattered spaces in written records of deeds.

8. Simplicity of description. number of the parcel being given, the length of lines, acres, etc., can be omitted as information shown by the map, and usually expressed in better terms than by words attempting to transcribe from

9. By means of the greater ease of graphic representation the burden of taxation can be more equitably adjusted; each owner's interest can be marked off, and in this way none need be overlooked or forgotten.

10. Greater simplicity, uniformity and

certainty in the work of the surveyor, and North-western Pennsylvania. fication.

Although something of a regular sub-United States ever since its first occupation by Europeans, very little in this direction was attempted in early colonial history, probably because its advantages were not appreciated as in later times. this respect did not advance much bethat seem best adapted for the plow, and the fields were consequently often of irregular outline, and the fashion of the times was to build stone walls after the English practice, not only for their permanence, but as a good way of ridding the fields of unwelcome bowlders. An inspection of village plans will show great irregularities, and to one accustomed to regular lots and rectangular crossing of streets such plans are a curiosity. Not only are the lot lines twisted about to an streets or highways are not always parallel to each other, or for that matter to anything else, but each side winds about regardless of its fellow.

In the State of New York there were formerly large holdings of a semi-feudal nature in several counties in the central part of the State. The patroons, as the prove them. In due time an official surholders of these large estates were called, veyor would be called up to mark out a leased out their land, refusing to sell. In tract of such shape as might strike the the course of time the tenantry became dissatisfied and the landlords not yielding to their demands, the famous antirent agitation of 1840-46 was inaugu- and worthless. rated, and though there were some agrarian outrages, the movement, which in rily abandoned before being paid for, a some countries might have amounted to not uncommon thing in pioneer experiform and became a complete success, ef-notions, but when once established they fectually breaking up such an unrepubliad to be followed by others. As may lican system. It is believed that the be imagined there was and still remains division of this territory is quite irreg-

ular.

lion acres of land in Western New York taxed. The unit of measurement used is

The the regular divisions being used as a name is derived from the fact that means of correction, adjustment and veriamong those who, at various times during the progress of the revolutionary war, loaned money to the Continental division of land has been possible in the Congress, were certain bankers in the old and wealthy Dutch city of Amsterdam. After the close of the war, being without other resources of repayment, this large territory was granted to a company composed of Harm Jom Huidekoper, Wil-The early settlers in New England in helm, Willink and others. The divisions were termed tracts and designated by yond English customs. Much of this number. They usually contain about country is rocky and broken, and that four or five hundred acres, being about a was first reclaimed from the wilderness mile in length, a common form being a mile east and west by fifty chains north and south. The dimensions and directions seem, however, to be often varied without other apparent causes than those arising from imperfect surveys. The shapes of the tracts were sometimes made long and narrow to secure a frontage on some river, as is often done in the early French grants so common in Canada, and sometimes recognized and perpetuated in our public land surveys.

A very common practice in the wild unnecessary extent, but the sides of the and mountainous parts of Pennsylvania is to divide the land into tracts containing about a thousand acres. In some places, however, the State lands do not appear to have had any division at all. To encourge sale and settlement a sort of pre-emption or homestead right was given to whoever would settle and imsettler's fancy, the main object being to inclose as much good land as possible, and leave out what seemed to be sterile

Very often these claims were voluntaoutbreak or insurrection against ence, and subsequent settlers ran new constituted authority, took a political lines more in accordance with their own some confusion and overlapping of lines, and many nooks and corners were left One of the earliest examples of diviout until the land became more valuable. sion by number on a large scale is that Though these surveys were recorded, afforded by the Holland Land Company's complete maps of such territory are very large tract, which embraced several mil- unusual, and some of the land is unacres, "together with the usual allowance of six per cent. for roads," etc. Without this allowance it is called strict measme

The Western Reserve of Ohio is a district which is comprised of the counties of Ashtabula, Trumbull, Mahoning, Lake, Geauga, Portage, Cuyahoga, Summit, Lorain, Medina, Erie and Huron, with a part of Ashland. About the beginning of this century this territory passed into the hands of the Connecticut Land Company, which was organized in 1795, with a capital of \$1,200,000, there being 4,000 shares of \$3,000 each. The purposes of the organization were merely temporary, inasmuch as instead of selling out the plan. land, and dividing the proceeds, a partition of the same was at once instituted an and carried into effect. Townships five miles square were laid out and numbered as ranges and towns, the ranges westward from the Pennsylvania line and the towns northward from the forty-first parallel of latitude, a system similar to that just previously introduced in the survey of the public lands adjoining. township might be called the unit of the land company's division, the theory being that the townships were of equal value, inasmuch if by reason of an undue proportion of swampy or waste ground any one of them was deemed less valuable than the others, the adjustment was made, not by changing the price, but land in another township was added to it to bring it up to the average, the process being called were cut up into strips or parcels for such | day. a purpose were called equalizing townships. The townships in this way having been brought to an average value, they were drawn by lot by the shareholders; and when this was done, the main object of the company was accomplished. The only surveys made by the company, this purpose, dividing the townships only

the perch, divided into tenths, and for into lots of from one to two hundred every acre sold six per cent. is added or acres each. If there were several pro-"thrown in," for instance, an hundred prietors, the interest of each were called and six acres is described as one hundred tracts, being designated by number, location as to north, south, east, or west, or taking a name from that of the owner, and their further divisions were known as lots. The survey of the townships by the Land Company was begun in 1797, and mainly finished in the course of four or five years. The division of the townships was begun immediately afterward, and very generally completed in the next ten years, or by 1815.

In some cases the owners of the tracts were in no haste to make sales, and consequently no division was made until a recent period. Other owners made sales from time to time without ever making a general survey or adopting a uniform

In Summit county is the Portage Path, ancient Indian trail about eight miles long connecting the waters of the Cuyahoga and the Tuscarawas. trail passes near the city limits of Akron and crosses the water-shed between the St. Lawrence and Mississippi basins. At the beginning of this century it was a well-worn footpath through the forest, The and as such it had been used by the Indians for a longer time than their traditions extended. It was so well-defined a highway that it was often a dividing line between tribes, and for a number of years was by treaty the line of white supremacy. Probably every vestige of the trail itself has now disappeared, but by surveys its location is fairly established and marked, a necessary circumstance, inasmuch as this ancient trail of the savage equalizing, and those townships which is the line of individual ownership to-

That part of the Reserve embracing 500,000 acres covering Huron, Erie and parts of Ashland and Lorain counties, which is known as the Fire Lands, was granted to the inhabitants of New London and other towns in Connecticut, who had sustained losses mainly by fire from therefore, were such as were required for the incursions of British troops during the revolutionary war. The loss of each where necessary for equalizing, and in individual having been determined, their such further division as was necessary to interests were placed in the hands of put the land into market, each proprietor trustees who, following the example of acted as he saw fit. Generally speaking, the Connecticut Land Co. in the other without noting exceptions, if a township part of the reserve, made an actual parhad a single proprietor it was divided tition of the land and distributed if by lot, the partition, however, affording much smaller parcels. The first division was to cut the township into four quarters called sections, and numbered thus—



Each section would therefore contain about four thousand acres.

These were again subdivided into tracts and lots, and although no great uniformity was observed it had the advantage of being done by one authority and at one time, and what is of scarcely less consequence, very fair maps were made and the field notes, etc., generally preserved, and are now extant in a good state of preservation at the recorder's office of Huron County, the original limits of which formerly comprised the whole of the territory

in question.

In this respect at least the trustees discharged their duties more faithfully than did the Connecticut Land Co., who were very remiss about getting up maps, having field notes kept, much less to preserve them; and as for the private survey of townships, the taking of field notes and the compilation of maps was something that rarely received proper consideration, and sometimes none of any consequence were ever prepared, others have been lost and others are comparatively inaccessible to the public, being in the hands of private persons, who consider them little better than old rubbish that they are gradually getting rid of. The only systematic attempt to collect these maps and papers is that made by the Western Reserve Historical Society.

The execution of these early surveys was often very imperfect. The instruments used consisted of a two-rod iron chain and a small compass with a needle four or five inches long. Though the surveying party usually consisted of but four men, besides cooks, packmen, etc., the lines were run with great rapidity, sometimes ten or twelve miles a day. The ground, place the compass upon it, level it with the needle (the only means afforded),

instead of sighting to a pole or staff held by an assistant, would pick out such tree or other object ahead that was on or near the line of sight. A glance was usually sufficient, and then the surveyor would set out to the point observed to repeat the process, while the chainmen and the marker would follow after, the latter blazing such trees as were within his Though the country was thickly wooded, it was often comparatively free from undergrowth. It was often possible to see to a considerable distance, so that with a little care the lines could be made straight for some distance; and, the ground often being nearly level, could be measured with considerable accuracy. Such results were, however, rarely attained, and in many instances the imperfections are so great as to be best accounted for by the old traditions, that the whiskey carried to prevent the bad effects of the bites of the then numerous rattlesnakes sometimes got into the heads of the whole party without improving the character of the work.

It is doubtful, taking into consideration the better general surface of the country, whether the actual work of the surveyor on the Western Reserve of Ohio was as well done as on the Holland Tract, and it is believed the records are not as perfect; but there was one great advance made, and that was in laying out regular numbered townships. Both were faulty from the absence of any well-defined plan of numbering tracts, and still more so in the neglect of the consideration of future sub-

division.

One feature of the partition of the Rererve seems to be especially novel, and that was the ingenious method of equalization heretofore described, by which the units of division that had been determined upon were kept uniform. This principle could be adopted with advantage in a great variety of circumstances where land is partitioned off in severalty among those who have hitherto owned it in common. In attempting to adjust the different interests to the varying value of the land, regularity and symmetry of form are usually lost sight of, and thus a permanent disfigurement of outline may result surveyor would plant his Jacob staff in the from a merely temporary cause, that might be easily avoided if, instead, a regular division is made, with uniform units, makthen setting it in the desired direction, ing the divisions of average value by adding fractional parts from divisions reserved

for such a purpose.

Connecticut, though perhaps the most persistent and unfair of them, was not the only claimant of the northwest territory. Virginia asserted her right to a portion of it, and there was, in consequence, granted to that State certain lands in Ohio lying between the Scioto and Miami rivers. It was set apart for the benefit of revolutionary soldiers, hence the name of Virginia Military District. No systematic survey of the territory was made, but the early settlers picked out the land wherever they could find any that was vacant, and of such shape as suited them best, those coming later being more and more retricted as the process of selection pro-Everywhere there is great variceeded. ation in the area of adjoining tracts, and in hilly districts and along the rivers, especially, very irregular boundaries. tracts are numbered, not, however, in their geographical order, but merely as to their time of location, perhaps the only way possible under the circumstances, but rendering the numbering of little practical use.

THE PUBLIC LANDS.

The plan pursued in laying out the public lands need not be described here further than it provides for townships six miles square, and sections one mile square. Considering the lack of precedents the plan is deserving of the very highest

praise.

There is one drawback which many must have felt if they have never complained of it, and that is the awkward way of numbering the sections. A more confusing arrangement could not have been easily found, and many persons after long practice are unable to mentally locate them in their relative order. While the ancient Hebrews wrote from right to left, and the Chinese arrange their characters in vertiling trees. cal columns, such is not the most convenient way for people accustomed to other methods, and it would have been vastly simpler and more easily remembered if, in numbering sections, they had been arranged as ordinary writing is margin.

In this plan, which might be termed a

alluded to, not because a change is now recommended, or because the plan shown is a perfect one, but simply to call attention to the general subject of numbering —something not without its importance —as an instance where correct principles are entirely disregarded. The system is, however, uniform throughout a vast territory, and once learned, in connection with the more simple notation of the meridians, parallels, townships and ranges, locations are easily described, and as the sub-division of a section is well provided for, definite descriptions of small parcels of say ten acres can be given without reciting the length or direction of a single

STATE OF THE PERSON NAMED IN	1	• 2	3	4	5	6
	7	8	9	10	11	12
	13	14	15	16	17	18
	19	20	21	22	23	24
	25	26	27	28	29	30
	31	32	33	34	35	36

This has greatly simplified the work of the conveyancer, the abstracter, the assessor and tax gatherer, as well as that of the surveyor. For the ordinary operations of the surveyor the sectional system is admirable. The original field notes and maps are a matter of public record, and show very full details of the length of lines, the meandering of streams and a description of the corners and bear-The corners of a section or quarter section once established the subdivisions are matters of bisection and distribution, and thus working from the whole to parts, bearing a numerical ratio to it, great accuracy is possible, in particular those due to imperfect standards of something as shown in the plan in the measure can be almost entirely eliminat-

In an open or level country all of the natural or obvious one, the numbers in- corners along a section boundary can crease downward by regular addition of generally be put into a single line, thus six. This matter of numbering is here fixing the position of a line by points

depending on cross measurements or used instead, and the intermediate points put in the same way without any unreasonable expenditure of time in run-

ning long lines.

in the general plan of laying out the public lands will not now be discussed. The more noticeable faults are not so much of deficiency of plan as those caused by defective execution of the surveys. Being done on the frontiers of civilization, the work is at best done at a disadvantage, and often with considerable hardship, if not actual peril to those engaged in it. There is little inspection by competent officials, and still less criticism through the effective process of public opinion. As there is competition the work must be done cheaply, and of necessity rapidly. Patient, thorough work takes time and money—sometimes so much that an accurate survey would cost more than the land was worth.

These contract surveys are, however, often erroneous beyond all excuse, and the marking of corners little more permanent than the surveyor's own footprints; and, worse still, though full sets of field notes were returned, they were made up from imagination, no survey having been made at all. It is generally possible, however, to make resurveys, and thus obviate some of the inconvenience

arising from this source.

That there should be great precision is not often possible under the circumstances under which the most of such surveys are made is no doubt true, and the absence of it is not of itself so serious a matter as many are apt to believe. Indeed, the thing of most importance besides the prevention of unnecessary and easily prevented errors, is the conspicuous and permanent marking of corners. This well attended to, minor inaccuracies of measurement and area may be overlooked as a matter of less importance, and which can be attended to and improved upon as increased values justify more accurate surveys.

That the plan of laying out the public lands is perfect would not be claimed. Doubtless something of value could be learned from the experience of Canada

beyond it in its own direction, and not and other countries which have had occasion to solve the same problem. In Canrectangular co-ordinates. In wooded or ada the principal of decimal division is hilly districts the half-mile points can be recognized, but a description of the system is omitted from lack of time to fairly present it in these limits.

But the sectional system is so far in advance of any examples previously af-The improvement that might be made forded in any of the older States, it might be termed, in comparison, perfection itself. Nor is it believed on an average that its execution is worse. It is interesting to observe after the lapse of thirty, forty or fifty years, or even longer, since the settlement of particular districts how closely the lines of ownership follow the section lines.

> Among the earliest of these sectional surveys are found in Columbiana, Carroll, Stark and other counties-in Ohio. Though over eighty years have passed, and several generations have occupied the soil of these important and thriving civil communities, the sectional divisions are by no means supernumerary or obsolete, the most noticeable variations being found in the hilly districts, where the reads are necessarily winding, and in some instances the deep ravines have been used instead.

> In the more level districts the variations are exceptional, and in many counties in States farther west such variations are almost unknown.

> The credit of designing the public land system has been usually awarded to Col. Jared Mansfield, Surveyor General of the United States. The great Jefferson, it is said, also honored the subject with his attention, and doubtless each of these and others did something toward perfecting and shaping the plan adopted, but Col. Charles Whittlesey, an authority of the very highest respect, in his valuable paper on "Ohio Surveys," recently published,* is inclined to award the palm to Thomas Hutchins, as the man in whose brain the conception first found lodgment, and who was one of the instruments in having it adopted. The honor is a great one, and his name may be fitly listed on the roll of great benefactors of mankind.

> Hutchins was a captain in the Sixtieth Royal Regiment, and engineer to the expedition under Col. Henry Bouquet, in 1764, during which time, in the lonely

^{*} Transactions Wes. Res. & N. O. Historical Society, Tract No. 59.

forests of Ohio, remote from the scenes thing for small lots and business centers. of civilized life, and from contact with It would at least require greatly increased men or their accumulated experience, as care in making the surveys, or the resrecorded in books, he evolved in his mind toration of lost lines be very difficult and the outline of the plan which was after- uncertain. ward adopted with but little change during the time he was geographer to the spider offers us a most admirable plan, confederation, an officer similar to the and the national capital has been laid surveyer-general, afterward filled Mansfield. Hutchins died in Pittsburgh another instance being the little city of in 1788, and his remains lie unnoticed in the cemetery of the First Presbyterian there is also something of the same sort, Church of that city. History has certainly done him scanty justice, and it is worth while to have said a few words to do something toward rescuing his name from oblivion.*

The principle of rectangular division was adopted at a very early period in laying out American cities, the most noticeable exception being in Boston. New York, Philadelphia and Chicago are laid out with great regularity, and even in Boston the newer parts are laid out in the same fashion. In the western cities the public land system affords an excellent basis. In Chicago, for instance, many of the well-known thoroughfares, such as Madison, Twelfth, Twenty-second, State and Halsted streets, and Ashland and Western avenues, are upon section lines, and many of the other streets are upon regular fractional divisions of

The rectangular system has been criticized mainly from its lack of convenience when it is desired to take a diagonal course, and on account of its supposed offence to an artistic or an æsthetic taste. To meet this latter objection some towns, mostly suburban, have been laid out, an instance in point being Riverside, near Chicago, where the lines of the streets or cemetery. However well such an arample grounds, it might be quite another modern assessor.

Some writers urge that the web of the by out with some reference to this theory, Watertown, New York. In Cleveland though fan shape would perhaps better describe the flare or gradual divergence from parallelism exhibited by Superior, Euclid, Garden and Woodland streets and avenues. If it were a fact that everyone must daily or constantly go to a certain point—say, for instance, to the post office—no arrangement could be better, and anything else would be so exasperating as to force the opening of new avenues to bring it about.

Such is rarely, however, the case. The business and manufacturing interests of a modern city are often widely scattered, and rarely tend to a common focus sodefinite as to require any such arrange-There are east sides and west sides, north ends and south ends, uptown and downtown, water fronts and railroad fronts—each with its own interests and attracting its special following.

The advantages of representing upon paper the ownership of land are so varied and serve so many public ends, that in a progressive community it is regarded as something indispensable. One of the first attempts of this kind was when, nearly nine hundred years ago, in the reign of William the Conquerer, the celebrated Doomsday Book was prepared. Officers were appointed to traverse the kingdom and are made up of curves something in the make out a list of the landowners (loyalty manner of the walks or drives in a park to the sovereign being, of course, a condition of ownership) and their possesrangement might suit for residence with sions, something after the manner of the The book is still extant, and has always been regarded as an authority almost as conclusive as inspiration, the object for which it was prepared being to inform the monarch of the resources of his kingdom, and on whom he might call for support.

It is something over one hundred years ago since the British ordnance survey was begun. Its original object was to make a map of the kingdom for the

^{*} Since the above was written there has appeared in a recent number of this *Journal*, Vol. 2, p. 282, an interesting and valuable article on "The Origin and Authorship of the Present System of Government Land Surveys," by H. C. Moore, of St Louis. Mr. Moore has looked up at the Marietta, O., University some of the original papers of Gen. Rufus Putnam relating to the Ohio Company's purchase, in which the plan is outlined as early as 1733. To fully settle the question is a matter requiring further research. Very possibly the result of such investigation would be that the honor is to some extent a divided one, inasmuch as the plan may have been developed, modified and changed by different persons. different persons.

use of the military authorities; but, as it progressed, its scope has been enthorough representation of the topography of the kingdom. The fullness of its detail may be judged by the scale used, that for the whole country being $\frac{1}{2500}$, and for villages and towns $\frac{1}{500}$. It would seem possible, from such a map, to make a very close approximation of the proper route for a railroad or similar public work.

In this country the preparation and publication of maps, except of the sea coast, the great lakes, and some of the uninhabited territories and mineral districts has been mainly through private enterprise, which has rarely conducted surveys of any consequence; and, where there are no regular divisions, such maps are necessarily incomplete to an extent that something more thorough and extensive is now a well-recognized public need, and, with the constant reiteration of the demand, may be set down as very likely to be early undertaken. But. whether such a general survey is made or not, the existing divisions, especially the regular ones, should be kept They are the framework or skeleton to which all ownership clings, and the preservation of their corners and their restoration and marking when lost may well, and ought to, receive the attention of the State, and be no longer left to the caprice of individual interest.

Whatever may be accomplished in a general way by geodetic and trigonometric surveys, the importance and necessity of which need not be undervalued, however fully and satisfactorily they may solve various interesting and important scientific questions, as, for instance, the figure of the earth, as well as serving many practical ends in map-making and the accurate determination of levels, the representation of contours, and in so many other ways justify their existence to an extent that will make their cost seem insignificant in comparison to the results attained. It is, I think, a grave mistake too generally prevalent to suppose that the lines laid down by such surveys will ever be generally relied upon to establish the lines of individual ownership. In the nature of the case the lines

sion, and, however carefully selected and good originally, in the lapse of years may larged, until its aim is a complete and become wholly unsuitable by reason, for instance, of the erection of buildings or the growth of trees. The initial points, too, will often occur in fields, or at points where no one is specially interested in their preservation or to be informed of their whereabouts, or, if often resorted to, might cause complaint from the farmer who might find it convenient to have them removed. It must be borne in mind also that were such points used, and the angles turned from them, it would still be necessary then as now to actually run, measure and mark the property lines, for that indeed is the object for which nearly all land surveys are made. In actual practice the accurate determinations of and marking of lines of the various trigonometrical surveys has not often been carried down far enough to make them convenient for such use, much of the detail work having been done with the plane table. The restoration of lost boundaries, too, is often a question of evidence, much of which can only be found on the line itself. Such is the rule of law, the final arbiter, to which all must submit when controversy ensues.

NEW METHODS OF PRODUCING STEEL PLATES. -Dr. Henry Muirhead, President of the Physiological Society of Glasgow, has recently brought before that body some particulars of a method of manufacturing steel plates for shipbuilding and boilermaking purposes which is of much interest, although its leading feature is not a novel one. It is the invention of Mr. Joseph Whitley, of Leeds, who has erected works for prosecuting the manufacture. Briefly describing the process, Dr. Muirhead said, a hollow metal cylinder, lined with ganister or other brick, revolves at high speed, the axis being horizontal. A gutter or rhone perforated with holes passes into the interior, along its whole length. Into this gutter is poured molten mild steel, which, escaping through the holes, is carried round by the swiftly revolving case. and is formed into an inner cylinder of steel of an inch or more in thickness. This cylinder, while still hot, is drawn, cut across by means of a saw, put into a rolling mill, and rolled to the length and thickness required. Writing to Dr. Muirhead, Mr. Whitley said: "Required a plate for shipbuilding; then, given a mould 5 ft. in diameter and 5 ft. long, in it I cast a cylinder an inch thick. This when taken out and cut is fully 15 feet long and 5 ft. broad. It is then relled down to helf an inch in thickness. then rolled down to half an inch in thickness. Such a plate is then 30 ft. long and 5 ft. broad. of a trigonometrical survey are largely artificial ones, made for a particular occa-steel shell weighing about 30 cwt."

YACHTS AND YACHT SAILING IN 1884.

From the "Nautical Magazine."

just commenced is likely to be a good last inside. Her frames are steel, topside one for yacht racing, that contests promise to be more than usually numerous and prizes more than ordinarily valuable. The old British cutter rig reigns supreme, schooners and yawls being scarcely heard Southampton, for Mr. John Jameson, but of. It appears that the extreme types of it would appear that she is hardly likely the last few years are only giving way to something more extreme, and that the divergence between cruising craft and vessels built for purposes of racing is greater than ever. The turn-out of the present year is chiefly in the smallest and largest vessels; new three-tonners are pretty numerous, and there are three likely to make 1884 a notable year in the competitions between large cutters. All of them are composite boats, and we may say that this system of construction, combining as it does great transverse strength with lightness of build, together with the advantage of coppered bottoms, is likely to keep its ground for pleasure craft, the expense of building, which is a bar to its use for merchant sailing ships, being of comparatively little consequence in the case of yachts, while its peculiar advantages in them are of greater value.

We may first mention the Genesta, built for Sir Richard Sutton, by Messrs. Henderson, of Partick-on-the-Clyde. Her length on the water line is 81 ft., registered length 85.6 ft., beam 14.6 ft., depth of hold 11.75 ft., greatest draft 13 ft., and register tonnage 74. She is described as having a very clean afterbody, but rather fuller forward than other recent yachts. Her racing tonnage is 80, and she carries 64 tons of lead ballast, of which 60 tons is in the lead keel. It was said that she would sail her first race in the Royal Thames match from the Nore to Dover on the 7th June, but she is at present in Cork, repairing damage sustained in her first sea cruise.

The Marguerite, of 60 racing tons, beam 13.5 ft., and draft 12.5 ft. She has lead of about $7\frac{1}{2}$ tons on the keel. She is

It is said that the season which has a lead keel of 51 tons, and 6 tons of balplank teak, and bottom pitch pine, and it is said she has a greater sail area than ever before carried over 13½ ft. beam.

The *Irex* is building by Mr. Fay, of to be ready for the earlier races of the season. Her dimensions are-length on water-line 83 ft., registered length 88 ft., beam 15.1 ft., draught 14 ft., register tonnage 75. She will carry the heaviest lead keel ever cast, nearly 72 tons. also has steel frames.

"These three vessels," says a recent racing craft of the largest size which are writer in the Times, to whom we are indebted for some of the preceding figures, "will, with the Eryana, Marjorie, Vandward, and Samena, make up a goodly fleet indeed of heavy weights. The forties, which showed such grand sport last season, are not likely to be in force, but new boats in the twenty, ten, five, three ton, and the length classes will invest the battles of those sporting sections with new life and interest. It is only reasonable to assume that a forward movement in regard to speed will be apparent in the three new vessels before referred to." Of the four vessels named as conspicuous in last year's racing, the first two will have more sail area than previously, and hence it will appear that both as regards new craft and improvements in old ones there is likely during the next few months to be keen competition for prizes.

One feature common to the three vessels, of which we have given the dimensions above, cannot fail to have escaped notice, the extraordinary amount of lead ballast and the great depth compared to beam now characteristic of the racing yacht. In smaller craft these features are even more strongly marked. new yacht at Plymouth is described by a correspondent to the Field, as follows: launched on the 12th ult., from Messrs. —"I judge her to be about $11\frac{1}{2}$ tons dis-Inman's yard at Southampton, for Mr. placement, strongly built, with the scant-Foster Connor, has a length of 74 ft., lings of a 10-tonner. She has a lump of over 30 feet on the water-line, with large overhang and flare abaft, and will draw 8 ft. How much farther is this 3-ton folly Mr. Dixon Kemp, who has written so much and so ably upon the whole question, attempts in a recent number of the Field to answer the question thus put by reference to a design to which has been given the name Ne plus ultra. It is intended to show the longest and narrowest yacht possible under the present Yacht Racing Association rule which a crew could live in, unless, as her designer says, "a man succeeds in getting a thin crew accustomed to sleep on their sides, and who would not mind coming on deck to turn round." reductio ad absurdum of modern yacht construction, described by Mr. Kemp as "the plank on edge," has a length on water line of 38.5 ft., beam 3 ft., and draft 11 ft., her load displacement being 19.8 tons, of which 15 tons is lead ballast on the keel. The tonnage by the Yacht Racing Association rule is, as we have indicated, 3 tons; in fact, a start is made with 3 ft. beam, and then to give 3 tons by the formula,

$\frac{(\text{length} + \text{beam})^2 \times \text{beam}}{1,730}$

the length necessary is 38.5 ft. By the Royal Thames rule, which is even still more applicable to present types, and of which the formula is

$$\frac{(\text{length} - \text{beam}) \times \text{beam} \times \frac{1}{2} \text{ beam}}{94}$$

the tonnage is 1.7, while by the sail area rule, at present admitted as an alternative rule by the Association, the tonnage is 12. The formula for the sail area rule is

$\frac{\text{length} \times \text{sail area}}{6,000}$

In each of these rules the *length* is length on the water-line. From what we have said it will be thus evident that yachtsmen are as far off as ever from a system of measurement which will give an equitable basis for time allowance, and that the present methods are but a very small improvement upon the old one. The alteration of the time-honored rule of the Royal Thames Club, which was for long the standard everywhere, was rendered necessary by the appearance of the *Jullanar* a few years ago. In the old rule

the length was taken from stem to sternpost, and the Jullanar, of which a detailed and interesting description is given in Mr. Kemp's "Yacht and Boat Sailing," has about 10 ft. of immersed counter abaft the post. To meet this new departure it was decided to measure length on the water-line. At the time that further changes in the yacht tonnage rules were under discussion, we suggested, not as a theoretically exact rule, but as a good practical solution of the difficulty. a system of measurement by which the product of the three important dimensions—length on the water-line, beam, and draught-should be multiplied by a factor, determined so as to give an average result not far from the present nominal tonnage of vessels of reasonable form and dimensions. This, we still think, would have been better than the rule which was adopted, and would have been at least more easily ascertained than the sail area tonnage, now so extensively advocated, although there can be no doubt of the fact that the sail area rule is a much better measure of size than anything else at present in force.

The ideal system of yacht measurement was recently described by Mr. R. H. Froude, an eminent authority on scientific questions connected with naval architecture, as one which should "handicap all tendencies to depart from an ideal form and fitting up of a yacht." These few words indicate the whole difficulty, as probably no two yachtsmen would agree as to what was an ideal yacht. It is in the nature of things, that whatever rule is adopted, there will still be racing yachts and cruising yachts, and that the vessel which excels in one respect will be at a disadvantage in the other. there can be no doubt of the faultiness of a rule which induces a designer to use upso large a portion of his displacement in carrying an immense lead keel, thus uselessly increasing the expense of the vessel, for no commensurate advantage. While remarking upon the prominent defects of the present type of racing yacht. it must, however, not be forgotten that they have usually a very large range of stability, and are, in fact, life-boats which

it is impossible to capsize.

the standard everywhere, was rendered necessary by the appearance of the Jullanar a few years ago. In the old rule a committee of thorough yachtsmen should

decide, among existing forms of yachts, vessel with still more lead, and then the which are eminently their ideas of cruis- ex-racer is next to useless. ing yachts. (2.) That by obtaining pracstates of weather, purely empirical diagrams should be drawn up, showing to struction against wood should be handicapped, to what extent difference of area of sail should be handicapped." He also suggests that "with regard to area of full sail, it seems to me that to obtain the sailto her sailing inclination, with a tackle attached to a spring balance, is a much more satisfactory method of working to the same object, as it leaves the yacht free to adapt her canvass to the weather and the inclining moment of sail area, corresponding to a standard angle of inclination. This depends upon the area and the height of the center of effort of the sail, and thus includes the element of height of sail twice, but a rule could be framed whose practical effect would be to eliminate the extra dimensions.

It is said that during the present season sail area rule of the formula we have given; of yachtsmen is that the vessel's tonnage this recommendation. Valuable informarig. The grounds upon which we advo-vessel, and as to the value of classes in cated a rule based upon the three princi- Lloyd's Yacht Register, and in regard to sail-power depends upon length and and illustrations of the various items. stability, while stability depends upon One chapter is devoted to the special beam and lowness of the center of gravity, question of seamanship, and another to equality with racers, but it would be easy of the Nautilus type—that is, craft fit to to reduce the present wide disparity, and sail on comparatively rough water, having keels. There is the further objection to a vessel propelled with a paddle or with racing yachts of the present type, that sail by a person or persons facing forward; the lead keel and its connections neces- she is a vessel capable of navigating shalsary, make the vessel very costly, while low water as well as open rough water, as things have gone of late years she is and she is a vessel not too large or heavy only successful till a designer produces a for land portage by two men when her

Mr. Dixon Kemp's "Manual of Yacht tical tests on different days in various and Boat Sailing" takes rank as the standard work upon the subject, and must, since its first publication, have been of what extent additional length should be invaluable assistance to owners of pleashandicapped, to what extent iron con- ure craft, from the dimensions of the racing cutters we have been describing to the tiny sailing canoe. In the earlier editions there were sections treating of yachtdesigning; they, however, have since been embodied in a separate work, and, in its carrying power by heaving a yacht down later form, the Manual has been entirely devoted to those parts of the subject which are of interest to the practical yachtsman. No pains have been spared to make the work a complete guide to the selection, management, and racing of points of sailing during the race." What pleasure craft of all sizes and descriptions. Mr. Froude thus proposes to measure is There are, moreover, special chapters upon local types of boats and yachts, showing how special forms of vessels have arisen either from local exigencies or fashions.

Mr. Kemp begins by advice as to the selection of a yacht, and comes to the conclusion that for cruising craft the rig should be cutter up to 80 tons, yawl from 80 to 150, and schooner above that tonnage; for racing craft he favors the cuta number of clubs will try the accepted ter, but recommends a moderate tonnage, and, in view of our previous remarks upon the principal objection to it on the part the subject, we should certainly endorse is subject to alteration by change in her tion is given as to examination of the pal dimensions of the vessel were, that the equipment, there are tables of sizes the latter in the case of ballasted vessels the special management required in yachtdepending upon draught. A good racing racing. By the title of Mr. Kemp's book, tonnage rule is certainly a desideratum, boat as well as yacht-sailing is implied; and and we should think the yachting com- accordingly much information is given munity will not much longer be without upon canoeing, this part of the work beone. No rule can, we think, permanently ing entrusted to specialists. Mr. Baden place comfortable pleasure craft on an Powell contributes the section on canoes afford room for the development of other good sheer, and yet coming under the and more desirable things than heavy lead definition of a canoe which he tells us "is canoe.

illustrated, are those on Lake Winderspread of sail. The remarks upon the ent season.

ballast and stores have been removed." Itchen boats are of additional interest Details of the construction and designs from the fact that the standard of value are given of several canoes of the Nau- for competitive sailing among them has tilus type and also of the *Pearl* type, the been length only. Other notable local latter being written by Mr. Fredwen the craft of which descriptions and designs designer of the original *Pearl* sailing are given are the Clyde yachts, Penzance canoe. Designs are also given of Mersey luggers, and a large number of center sailing canoes, and of an American river board boats of various types and sizes. There is a chapter on ice yachting, in Among the local types of yachts which the singular phenomenon of a vessel sailing faster than the wind is elucimere, remarkable for the long overhang dated, and an appendix contains a dictioncounter and heavy lead keels, the yacht ary of useful information on yachting. of the Norfolk Broads of an almost op- We believe that another edition of this posite type, yet both carrying a large valuable work is announced for the pres-

ON THE GASES SEPARATED IN STEEL CASTINGS.

By F. C. G. MULLER.

Translated for Abstracts of Institution of Civil Engineers.

The author in this paper replies to the criticisms on his former work contained author as the reaction theory, supposes in Mr. Pourcel's paper, read at the Vienna the separated gases not to be previously meeting of the Iron and Steel Institute, contained but to be formed at the moand to the remarks of Mr. Windsor Richment of separation by the reaction of disards upon it. After pointing out that the solved oxide of iron upon carbon. This cavities in unsound ingots are not the re- requires the gas in the pores to be of a sult of the enclosure of gas-bubbles in a liquid, but tubes resembling those of worms oxide, while in the absorption theory no produced by the separation of gas from particular composition is specified. The previously solidified metal, having their part may be played by carbonic oxide, as longer dimensions perpendicular to the well as by any other simple or compound cooling surface, he states that two theor- gas. ies of their origin have been proposed. The first of these, called the absorption theory, supposes that the fluid metal takes For instance, completely decarburized and up gases from the air or the fire, which are given out again on solidification and cooling. Such an action is known to take than any other kind, their volume being place with silver and copper, and an analogous action is seen in the freezing of not be due to reaction, as there is no carwater, where the dissolved air separates bon present. and forms cavities very similar in appearance and radial arrangement to those of an unsound steel ingot. It is not necessary to suppose that the whole of the gas of iron, producing silica instead of carso taken up is separated, a portion being bonic oxide, is contrasted with the cirretained at a temperature far below that cumstance that German Bessemer steel is by the mother liquor.

The second theory, characterized by the definite composition, namely, carbonic

The second theory is considered by the author as opposed to many observed facts. overblown metal, when cast without any additions, gives off more gases in setting many times that of the metal, which can-

Mr. Pourcel's explanation of the effect of solidification. In this respect the first rich in silicon, and yet unsound ingots separation of gas represents the first are common. Part of the author's excrystallization of mixed salts from a solu- periments were made with steel containtion, and the residuum, the salts retained ing 0.3 to 0.6 per cent. silicon and 0.8 per cent. manganese, and in the direct Besse-

mer process, steel with 1 per cent. of when chemically pure, give porous ingots silicon is often produced, which rises so from the separation of carbonic oxide and quickly that there is often scarcely time to stopper the moulds. Another fact is addition of 0.1 per cent. of lead is made that in recarburizing highly silicized steel with spiegeleisen, a violent evolution of nesium to the second when melted. It carbonic oxide takes place, showing that the reaction of carbon upon exide of iron is effective even when the bath contains a notable quantity of silicon. In some cases the author has found an actual inspiegel or ferro-manganese, showing that only the carbon and manganese of these compounds were effective as deoxidizing agents. Again, in the ordinary German Bessemer process there is no sensible oxidation of silicon so long as carbon is present, its behavior being, in fact, similar to that of phosphorous in the basic process.

Although, therefore, there is no ground for supposing that the mere presence of silicon in the metal hinders the formation of gas pores, it is otherwise when an addition of a silicon compound is made before casting. This the author considers to be a proof of the accuracy of the absorption theory, as showing the phenomenon to be merely physical in its nature. Silicon increases the solvent power of steel for gases, so that the bath, when previously saturated, becomes only partially so by the addition, and therefore separation is prevented. Of course, if the opportunity is given, it may become saturated a second time, and its solvent power may be increased by a second addition of silicon, and so on. The latter statement is only the solubility for gases is proportional to the content of silicon. It is more likely that an addition of 0.1 per cent. to a bath than an increase of an original 0.5 to 0.6 Martin process, where highly silicized compounds are most effective. This simple explanation, the author points out, has not only been previously published by himself, but was given by Mr. Gautier a Steel Institute.

That small additions of foreign elements fold volume. The author considers that materially influence the solubility of gases in metals is proved by the analogies of copper and nickel. These metals, which, Proc. Inst. C. E., vol. lx., p. 499.

hydrogen; cast perfectly sound when an to the first, and of 0.12 per cent. magseems, therefore, extremely probable that silicon may have a specific action upon iron of a similar character.

The author then reviews the various analyses of gases given off by steel, comcrease of silicon after the addition of mencing with those of Troost and Hautefeuille, in 1873, Parry's in 1874,* Regnard's in 1877, and his own in 1878-79. These are repeated at length, on the ground of their having been imperfectly reproduced in foreign journals.† The general result of the whole of these is to show that the gases liberated, whether by heating the metal in vacuo or boring it, consist essentially of 85 per cent. hydrogen and 15 per cent. of nitrogen. Mr. Stead's experiments, made for Mr. Windsor Richards in 1880, give an essentially similar composition. The supposition of the latter observer, that the hydrogen may be due to the decomposition of water by the friction of the metal against the borer, is shown to be untenable, as the shavings taken off when steel was slowly bored in air showed no tendency to tarnish, and if, therefore, there was no disposition to take up free oxygen, it is not likely that they would decompose water in a specially cooled apparatus in order to become oxidised. Even such a tendency, if it existed, would be checked by the reducing atmosphere produced when the first few centimeters of hydrogen had colput forward as a possibility, as there is lected in the bore-hole. The enormous no experimental evidence to show whether volume of gas, removed in Stead's experiment with the blunted borer, amounting to about eleven times that of the metal, shows that the whole of the intermoleccontaining none may be more effective ular gas has been removed, owing to the metal being practically pulverized. This, per cent. The first case is that of the however, is in accordance with the fact previously pointed out by the author, that the amount of gas removed depends upon the thickness of the shaving. That the volume of these intermolecular gases should be so large is, however, a new and year since, at the meeting of the Iron and important discovery. Parry, by heating in vacuo, obtained only a three to four-

these gases are actually alloyed in the steel; that nitrogen is actually so contained is proved by the admirable experiments of Allen, and he is now at work upon a method for the quantitative determination of hydrogen. Both elements are integral constituents of the steel, and possibly may exercise an important influence upon its physical proportions.

Carbonic oxide is also contained in the intermolecular gases, but as it is only given off at a red heat, and not in the boring experiments, it is evident that it forms a more stable combination with the metal than either hydrogen or nitrogen.

In conclusion, the author points out that the results of some fifty experiments, made by different observers in different ways, show that hydrogen is the principal gaseous constituent obtainable from steel, whether in the gases from the molten metal, the contents of the cavities in the ingots, or the intermolecular gases of the compact metal. Nitrogen is a neverfailing associate, while carbonic oxide is invariably subordinate in importance to hydrogen, and is never found in the larger It is most probable these gases are due to the decomposition of steam in the air or gases of the furnace, and that their effect can be neutralized either by the addition of silicon, so as to increase the solvent capacity of the metal, or that they can be separated mechanically by the rapid evolution of another gas on the addition of spiegeleisen.

REPORTS OF ENGINEERING SOCIETIES.

RIGHERS' CLUB OF PHILADELPHIA.—A special business meeting was held in Philadelphia, June 21, President Wm. Ludlow in the

Prof. L. M. Haupt, Chairman of Committee on Resolutions with regard to the proposed change in the United States Coast and Geodetic Survey, reported the following, which were unanimously adopted and the Committee dis-

"Whereas, We, the Engineers' Club of Philadelphia, have learned that a bill has been drafted in the sub-committee on Sundry Civil Appropriations of the United States House of Representatives, the purport of which is to merge the United States Coast and Geodetic Survey into the Navy and Interior Departments;

"And Whereas, Under existing laws and regulations, such a practical dissolution of this distinguished and efficient organization must result in a lowering of the high standard attained, without producing any equivalent on the score of economy or expediency;

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"And Whereas, The changes now proposed were tested, both in 1834 and 1851, and in each

instance proved a failure; therefore it is "Resolved, That in the opinion of the members of this organization the proposed change in the status of the United States Coast and Geodetic Survey would be prejudicial to the best interests of the government service.
"Resolved, That the members of Congress

representing the state of Pennsylvania be, and are hereby, respectfully and earnestly requested

to oppose the passage of this bill."

The Secretary having arranged therefor, copies of the above were forwarded immediately

after the meeting.

The Secretary reported upon the relations of the Club to the Custom House and Post Office, but delays his final report, as certain matters in relation thereto are still subject to controversy. Documentary and other evidence is on file, however, to show that the following are among the remarkable conclusions which have been reached by our government officials.

By the Custom House:

"1. That engineering societies, the objects of which are 'the professional improvement of its members, the encouragement of social intercourse among men of practical science, and the advancement of engineering in its several branches, are not scientific societies.

"2. That the liability of a package to duty

depends upon its size.

"3. That the Transactions of the Institution of Civil Engineers of England are subject to customs duty, and that the Transactions of the North of England Institute of Mining & Mechanical Engineers are not.

"4. That the Transactions of the Institution of Civil Engineers of England are worth about Sic Transit 'ad valorum' three cents each.

mundi!)'

By the Post Office:

"1. That while two cents per pound is the rate accorded to the general press, including certain pictorials about which all respectable people seem to have one opinion, a society the object of which is the dissemination of useful knowledge, must pay one cent for each two ounces and fraction thereof, or over eight cents per pound, on a publication issued as its own proceedings.

"2. That this Society is not entitled to 'the same low rates that are extended to the general public' under the recent law, making one cent for four ounces the rate at which an individual

can post a newspaper."

The report of the Secretary was referred to the Board with power to act. On motion of Mr. C. A. Ashburner, the club rooms were unanimously tendered to the local committee of the American Institute of Mining Engineers for their headquarters.

Mr. Horace See presented copies of indicator cards from the engines of the yacht "Anthracite," taken with 370 pounds boiler pressure per square inch, and steamship "Aberdeen," with 113 pounds, also a diagram showing curve of initial pressure of steam in the high-pressure cylinder of each vessel. The cards and accompanying table showed what the division of the work between two or more cylinders, so as to limit the range of expansion and temperature in each cylinder during one stroke, has to do with the economy of the steam engine, and that in utilizing the high pressures we must employ an engine with a degree of efficiency proportionate to the increase of pressure.

Mr. Charles A. Ashburner presented a brief description of the anthracite coal fields, accompanied by a geological map of the region, which will be engraved and published in the *Proceedings*. Among many facts relating to the geology and mining of coal, it was stated that, according to recent measurements and estimates made by the Geological Survey, less than 30 per cent. of the marketable coal contained in the high dipping beds of the Schuylkill and Lehigh basins had, during the past history of anthracite mining, been sent to market, while over 40 per cent. had been left in the mines for roof supports, and over 30 per cent. had been thrown on the culm banks as being too fine and dirty to ship. It is encouraging to know that within the last few years the 30 per cent. of actual fuel coal obtained has, in many cases, been increased to between 45 and 50 per cent.

Mr. McCreath's recent analyses show that the best coals from the Lehigh basins which can be had in the market, do not contain over 86.5 per cent. of fixed carbon, although these coals have generally been rated about 90 carbon fuels. It would appear that past analyses have been of picked specimens, while those collected by Mr. Ashburner have been samples taken from between 100 and 200 tons of the coal loaded on railroad cars ready for shipment to market. The spot value at the mines of Pennsylvania anthracite is equivalent to 92 per cent. of the spot value at the mines of all the bituminous coal mined in the United States, and 89 per cent. of the value of all the gold and silver mined in the United States.

Mr. Ashburner also presented to the Club a very fine shaded lithograph of the topography of McKean County, Pa.

Prof. L. M. Haupt added to his recent papers on rapid transit, statistics of the growth of cities as exemplified in Philadelphia.

The Secretary presented Mr. John Marston's reply to Mr. J. H. Murphy's discussion of the formula for turnouts and crossings, presented by him to the Reference Book.

The Secretary also presented the following Reference Book contributions: "A Co-ordinate Method of Ascertaining Distances in Cities, Applied to Philadelphia," by Mr. John H. Dye; "Relative Elevations of Certain Leveling Data," by the Secretary.

The Club adjourned for the summer, to meet at the call of the President.

ENGINEERING NOTES.

A New Paving Material.—The paving consists of bricks, 8 inches by 4 by 4, laid in hot tar on a bed of concrete, 6 inches in depth. In order to arrive at reliable conclusions as to the behavior of this paving material, it was laid down at the junction of the Leipzigerstrasse and Charlottenstrasse in Berlin, a spot over which the heaviest traffic passed; this was

estimated at one thousand vehicles per hour, besides one thousand three hundred tramcars daily. The material appears to answer its purpose admirably. Granite, compressed asphalt, and wood pavement had been previously tried on the same spot, and had all required repair after having been down three months.

The numerous attempts hitherto made to render bricks tough and endue them with a high fracture of resistance against pressure, by steeping or boiling them in tar, have all failed, because the bitumen is unable to penetrate to a sufficient depth. In this case, however, the bricks are placed in a vacuous chamber, hot asphalt being afterwards introduced By this means the brick is freed from air and moisture, and absorbs from 15 to 20 per cent. of bitumen; it becomes very tough and elastic, is capable of withstanding great pressure, and absorbs no moisture.—Deutsche Bauzeitung.

These bricks have also been used for dampproof courses, stable-pavements, retaining-walls,

N THE REMOVAL OF DEPOSIT FROM RESER-Voirs in Algeria.—The reservoirs in Algeria are of great size, and they are of immense importance to the prosperity of the country; after being constructed under difficulties, and at considerable expense, they are in danger of being completely filled up, unless means are taken for the removal of the deposit which accumulates rapidly in them. For instance, the reservoir at Saint Denis du Sig, constructed with a capacity of 122,000,000 cubic feet, had in 1879 silted up to the extent of 24,000,000 cubic feet. The Habra reservoir, constructed in 1871 with a capacity of 105,000,000 cubic feet, contained, in 1879, 70,000,000 cu. ft. of deposit. The same thing takes place, but to a less extent, in Spain, and the system adopted for cleaning the reservoirs in that country is to wash them out about once in every four years. This, however, not only necessitates the emptying of the reservoir, but also causes the loss of the sediment, which is generally very valuable for irrigation. The method of remedying the evil applied by the Author at Saint Denis du Sig, consists of blowing air into the sediment, thereby stirring it up and allowing it to run off with the water. The air may be compressed by means of turbines driven by the water as it passes out of the reservoir, conducted through india-rubber pipes over the dam, and carried down into the mud by an iron tube which is attached to a float, by means of which it can be moved from one part of the reservoir to another. The Author describes the apparatus in detail, and states that as the result of an experiment on a small scale (using a 12-HP, portable steam-engine for compressing the air), the water, clear at first, became rapidly charged with the stirredup sediment to a distance of 110 feet round the pipe. It is only necessary to inject the air near the dam, for, as the mud is removed from this position, a fresh supply flows down from the more distant parts of the reservoir, and this is in its turn stirred up into the water in a similar manner. The Author estimates the cost of an apparatus for cleansing a reservoir of the capac-

IRON AND STEEL NOTES.

N THE PRODUCTION OF CEMENT FROM SLAGS.

—By L. ROTH.—The author points out that Portland cement, and the slags obtained in the production of foundry pig-iron with coke, are essentially similar in qualitative composition, as is seen by the following analyses:—

	Cement.	Slag.
Lime	. 60.05	51.62
Silica	. 24.31	35.12
Alumina	. 7 50	9.53
Magnesia	. 1.17	1.58
Ferric oxide	. 3.34	
Ferrous oxide		0.87
Manganous oxide	· <u>·</u>	0.37
Potash	. 0.80	_
Soda	. 0.74	_
Sulphur	. —	0.88
Gypsum	. 1.82	
	99.73	99.97

In the slag, sulphur exists as sulphate of calcium, which would be injurious to the setting-power of the cement, and there is also a quantitative deficiency in certain bases. In order to supply these, the author mixes the slag with Bauxite and limestone, or lime, and moulds the powder into bricks, which are burnt in an ordinary cement-kiln, Hofmann's annular kiln being preferred. In firing, the heat is raised gradually from dull to bright redness, to drive off combined water and carbonic acid, and to convert a portion of the sulphide of calcium into sulphuretted hydrogen, and aluminate of lime; after which it is sintered at a strong white heat, and the resulting mass is crushed and ground in the usual way.

As the value of Bauxitc depends upon its contents of free alumina, the proportion added will vary with its composition; the limits between which the finished product may be regarded as

giving good cement are:

Lime. 55 to 63 per cent. Silica. 22 to 26 "Alumina. 6 to 10 "

The proportions used by the author, with a basic slag of the composition previously given, which falls to powder when cooled, are:—100 slag, 85 limestone or chalk, with CaCO₃, 98, and SiO₂ 2 per cent., Bauxite 15. The latter is the variety found near Giessen, which contains Al₂O₃, 48.5; Fe₂O₃, 13.52; SiO₂, 9.40 per cent.

This mixture when burnt gave 158.66 parts of cement, of the following composition:

	Per cent.
Lime	. 61,9
Silica	
Alumina	. 10.6
Ferric oxide	. 1.3
Ferrous and manganous oxides.	. 0.8
Magnesia	. 1.0
Sulphur	
	100.0

One half of the total quantity of the sulphur in the slag was eliminated as sulphuretted hydrogen. The cement, when ground and sifted was built of forty-one rails, each 3 meters long,

through a sieve having nine hundred holes to the inch, was of a greenish-gray color, and of strong hydraulic properties, showing no tendency to swell when once set. It is essential to the process that the materials should be perfectly mixed before firing. Slags that fall to pieces in the air should be sifted through a 900-hole sieve, but when they are not sufficiently basic they should be granulated in water when run from the furnace, and ground in the cement-mill. A small addition of soda may be made advantageously in some cases, but as a rule it is not necessary. The cement may be applied in the formation of articles in concrete with granulated slag, which possess a certain hydraulic character.—Abstracts of Institution of Civil Engineers.

RAILWAY NOTES.

THE annual report of the Dominion Minister of Railways, as presented to the Canadian of Railways, as presented to the Canadian Dominion Parliament, shows that during the year under consideration as many as 1275 miles of railway were added to the length of road in operation in the Dominion, making a total of 8805½ miles under traffic. The railway system of Canada will within the next two years, when all the uncompleted lines are finished, comprise something over 11,400 miles. The paid-up capital has increased during the year from 415½ million dollars to 4941 million dollars, or 19 per cent., an increase in the capital per mile completed and under construction of 17.03 per cent. The business done by all the lines in operation has grown in large proportions. The gross amount of freight carried during the year was 13,266,255 tons; and the gross receipts $21\frac{1}{3}$ million dollars. The number of passengers carried was 9,579,948, and the gross receipts showed an increase over those of the preceding year of $4\frac{1}{4}$ million dollars. The net earnings were sufficient to pay approximately a dividend of $2\frac{1}{2}$ per cent. on the share and bonded liability of the roads in operation.

ARTIGUE'S ELEOTRIC RAILWAY.—M. Lartigue, the well-known French engineer, has applied electricity to the traction of the panniers or cars of his single-rail tramway. This tramway is, as we stated some time since, employed in Algeria for transporting esparto grass from the interior by the traction of camels. It was an easy step from animal to electric traction, and M. Lartigue has successfully taken At the recent Agricultural Exhibition in the Palais de l'Industrie, of Paris, an experimental line was shown on which five iron panniers, or double cars in the form of seats, were drawn by a dynamo-electric locomotive at the rate of seven miles an hour. The total weight of the five cars and the electric locomotive was about a ton, and the maximum power required was three horse-power. The dynamo of the locomotive was a Siemens D6, and the generator, which stood about 100 yards from the line, was a Siemens D2 dynamo capable of developing from 5 to 6 electric horse-power. It was driven by a Herman-Lachapelle steam engine.

and comprised curves of 71 meters radius. The locomotive dynamo was carried by a platform car or pannier, and geared with a grooved driving wheel 30 centimeters in diameter, which ran upon the rail. A rheostat to graduate the speed, switches to stop, start, and reverse the motor, and a seat for the conductor, were also carried by the locomotive car. The train was properly coupled to the locomotive, and ran on small grooved wheels. The current was brought to the dynamo by two insulated conductors, one connected to the rail, the other to the dynamo through small contact rollers in connection with the commutator. One switch was employed to start or stop the train by making or breaking the circuit; the other to reverse its motion by reversing the current. The rheostat, by interpolating resistance into the circuit, allows the strength of the current to be varied and the speed of the train to be increased or diminished as the case may be. The work was carried out by Messrs. Siemens, and under the direction of M. G. Boistel. The economy of the working is of course largely dependent on local circumstances.

N ELECTRIC MOUNTAIN RAILWAY.—A pro-A ject has been formed, writes a correspondent, and will, in all probability, shortly be executed, for uniting the Hotel des Alpes, at Territet Chillon, and the Hotel de Mont Fluery, which is situated on the steep mountain side immediately above Chillon, by an electric railway. The difference of altitude between the two hotels is 180 meters, and the system which it is proposed to adopt was put to an experimental test recently. Rails of a gauge of 50 centimeters were laid on a part of the mountain for a length of 50 meters, and with a gradient of 30 to 100. Between the rails is a rack for the reception of a toothed wheel, and at each end is a curve in order to show the advantage of the proposed system over the funicular system, which does not admit of the slightest curve. The wagon carries a dynamo-electric machine, which actuates by special gearing a toothed wheel on the axle in connection with the rack between the rails. An electric and an ordinary brake enable the conductor to modify the rapidity of descent at pleasure. The electricity was produced for the occasion, and in the first instance, by a dynamo-electric machine of 5 horsepower, actuated by a portable engine. This engine it is intended to replace eventually by a turbine, for which there is an ample supply of water. The apparatus for the transmission of the electric force to the receiver on the wagon consists of copper cables laid between the rails and alongside the rack, and the electric contact is established through the intermediary of mechanical brushes in the usual way. The carriage, in which were seated two, three, and sometimes four persons, the whole, including the carriage, representing a weight of from 300 to 500 kilogrammes, went up the steep incline at the rate of from 1 meter to 2 meters per second, and the descent was completely controlled by the ingenious combination of the two brakes. In the of the federal government, the journey between the delay and obstruction which had taken

the two hotels may be performed in seven or eight minutes. As, moreover, water is plentiful in Switzerland, there is no reason why every fashionable mountain should not have its own particular electric railway, and the time may come when idle or infirm tourists will ride luxuriously across the Mer de Glace and be carried on wheels half way up the Jungfrau and the Matterhorn. Already the people at Geneva, encouraged by the success of the experiment at Territet Chillon (Montreux), are proposing to utilize the waters of the Arve for the ascent of the Saleve.

ORDNANCE AND NAVAL.

THE MONCRIEFF SYSTEM.—Colonel Moncrieff read at the United Service Institution, on Friday, April 25th, to a large audience, a paper on his system of mounting ordnance. Probably many of our readers have latterly lost sight of the Moncrieff system, and have assumed that for some reason it had not fulfilled the promise of which it once appeared to be full. Some of us probably assumed that it was found inapplicable to the heavy guns now employed, or that the carriages were too complicated, or, again, that there were objections to the receivers on the hydro-pneumatic carriages. If none of these things were true it was high time that Colonel Moncrieff should call attention to this important question, which had been allowed to lapse into oblivion.

In a paper couched in very mild and moderate terms, Colonel Moncrieff explained his case on Friday. He divided the methods of mounting guns into three systems: (1) Ordinary barbette; (2) iron casemates and turrets; (3) the protected barbette or disappearing system, commonly known as the Moncrieff system. The first system—the barbette proper—exposes the men so much that it was found even in the days of the American War that barbette batteries could certainly be silenced by armor-clad vessels. Since the introduction of machine guns this operation is easier than ever. The turret or casemate system is very expensive, and the guns have, in the case of casemates, but limited scope. Consequently Colonel Moncrieff urged that his system obviously met the need of the country by providing guns which combined complete protection with all-round fire, and which offered enormous saving in money. He informed his audience that the manner in which he had been dealt with was as follows:-Successive special committees had been directed to investigate the merits of his system. He had never failed to convince a committee after a time that his system ought to be adopted; so that each committee eventually recommended its adoption. This, he said, was always the signal for the abolition of the committee. Seven committees had eventually come to the same conclusion, and had been abolished at last. Colonel Moncrieff, who was then employed by Government, was himself abolished, that is to say, his appointment was done away with, he event of the project being carried into effect. himself being told that his services were not which depends to some extent on the approval further required. The crowning evil was that

place have acted as a vague argument against the Moncrieff system, which it is now urged has somehow failed to succeed. The Navy had wished for the Moncrieff system, so had the Royal Engineers; the entire fault he therefore maintained lay with the Director of the Artillery Department, who refused to make the carriages, and even to buy a carriage which was to be made by Messrs. Easton and Anderson free of expense. The Colonies had asked for the Moncrieff system, which is specially suited to the case of limited numbers of men; because fewer guns are needed, owing to the fact that all-round fire is possessed by Moncrieff guns, and also that the men are very completely protected and are likely to have very few casualties. Colonel Moncrieff read a letter from General Scratchley, R.E., the adviser to the Australian Government, saying that he had always advocated the adoption of the system, and pleading that the blame of its being prevented from coming in did not lie with the Royal Engineers. It appeared that in 1872 the Moncrieff system was first approved by a committee, and for fifteen years the process of ignoring recommendations made on the score of both efficiency and economy by committees has continued. Hence Colonel Moncrieff said that he felt it needful to speak out, which he did as a man in whom all enthusiasm had been extinguished, but who had full faith that his system must eventually be adopted, although, judging from past experience, it might not be in his lifetime.

In the discussion that followed, all the speakers sided with the lecturer. Naval officers, artillery officers, and engineers appeared to be in complete accord. Mr. Anderson was called upon to speak as to the application of the hydro-pneumatic system to heavy guns, and replied that the Russians had two 40-ton guns mounted on this system, and were so highly satisfied with it that they declined to try the Albini carriage. Admiral Ryder and Admiral Sir John Hay, Admiral Boys and Admiral Selwyn, Colonel Duncan, R.A., and others spoke. It was suggested to Colonel Moncrieff that perhaps he had proved his case too clearly and unanswerably for success; he was reminded how irritating a thing this is, and he was even asked whether he could not introduce some features that would furnish his system with such faults as would make it less obnoxious and more calculated to invite sympathy.

THE "DELTA" STEAM LAUNOH.—A steam launch constructed of "delta metal" was lately exhibited at the Crystal Palace in the joint names of Mr. Alexander Dick, the manufacturer of the new alloy, and Messrs. Yarrow & Co., the builders of the launch. As it has been proved by repeated experiments that the delta metal is equal in strength, ductility, and toughness to mild steel, the plates and angle pieces of this launch were made of the same thickness as if they had been of steel, namely $\frac{3}{32}$ in. The length of the boat over all, is 36 ft., the breadth of beam 5 ft. 6 in., and the depth from gunwale

the usual way. The angle frames are made of the same material and are placed longitudinally instead of transversely, to give greater longitudinal strength. The propeller cast in delta metal, is four-bladed, 2 ft. 4 in; in diameter, and 3 ft. pitch. The engine is of the usual direct-acting type, and of sufficient power to propel the boat at a speed of eight or nine knots per hour. The advantage of delta metal over steel and iron for shipbuilding, is that it does not rust. It is well known that a thin steel vessel, unless continually painted will rust through very rapidly. This difficulty has been found to exist to a remarkable extent in the rivers of Central Africa; in these the water, from some unexplained cause, possesses an extraordinary power of corroding and eating through steel plates. This fact is of special interest at the present moment when the rapid development of the African continent may be looked for. An important advantage possessed by delta metal for the construction of large boats, where its weight must be reckoned by tons, is that it is offered at a moderate price, and consequently the undoubted advantages of non-corrodibility are not eclipsed by a prohibitive cost.

BOOK NOTICES

Mining Engineer. 8vo. By M. Eissler, New York: J. Wiley & Son, Publishers.

In the book before us we have an attempt made at editing much useful information con-

cerning explosives.

The compiler has accumulated, from various sources, data relative to the chemical constituents and the methods of analysis which enter into the manufacture of high explosives. He treats in detail of the preparation of nitroglycerine, the various nitro-glycerine compounds, pyroxylin, gun cotton, nitro-cellulose, and the fulminating compounds. In the second part directions are given for using the high explosives, with special reference to the various processes of firing or igniting by means of electric machines, fuses, and similar appliances. The third division of the work is devoted to different methods of blasting, including special applications in various engineering enterprises from excavating tunnels or mining shafts, to the removal of stumps and the breaking of ice. An appendix, in which various theoretical considerations will be found, brings the work to a close. The theories of explosion, as put forth by Able and Berthelot, are alluded to and commented on.

That a book of this kind is needed there can be no doubt, and we regret extremely to find in a work, admirable in so many respects. the evidences of unfortunate ignorance or extreme carelessness. The section devoted to glycerin, which is fairly representative of the book, is so filled with mistakes and inconsistencies as to be utterly unreliable. Even a cursory glance will discover many errors in chemical nomenclature. On page 15 "three hydroxyl to keel 3 ft., the capacity being sufficient to provide sitting accomodation for twenty-five persons. The stern, keel, and stern-post are of forged delta metal, and are scarfed together in

bone coal (p. 25). The use of final e in glycerin is not accepted by the best writers in chemistry, but then no attempt appears to be made to follow correct usage in this respect. Even on the first page, Chili saltpetre is first written sodium nitrate and then sodic nitrate, thus tending at the very outset to confuse readers not familiar with the ancient and current chemical nomenclatures. We find also many instances in which the editor is inconsistent with himself; for instance, on p. 12, the table of statistics foots up 9,500 tons. while directly following it is spoken of as 7,500 tons. On the same page, glycerin is said to boil at 554° F., while on page 24 it boils at 618° F., which is correct—and why are not references given? On page 13 it is stated that glycerin crystallizes at 42° F. This is novel information, and we should be glad to know on whose authority this statement is There are also many infelicities and ambiguities, such as the following: "Small particles of soap conglomerate to small lumps" (p. 18). Sentences not easy to understand: "The method which is employed depends on the proceeding by which the fats are decomposed and the quantitative results of glycerin on them" (p. 16). In the saponification of tallow by lime, it is best to use little lime; and a high pressure, for instance, by employing one hundred parts tallow and four parts of lime. Several of the latest and most improved processes of extracting glycerin are ignored entirely.

The book, therefore, is not one that we can recommend to our readers. Those seeking a knowledge of the subject will be misinformed by a perusal of the volume, while those who use it for reference will find it so unreliable that they will be compelled to throw it aside as worthless. It can only be of service to such experts as are competent to separate the good from the bad, and even to them its utility will be slight. It is, however, an excellent specimen of mechanical book making, and while it evidences the good taste of its publishers, its best function will be to serve as a sample of fine

printing.

STEEL AND IRON. Comprising the Practice and Theory of the several Methods pursued in their Manufacture, and of their Treatment in the Rolling Mills, the Forge and the Foundry. By W. H. GREENWOOD, F. C. S., Assoc. M. I. C. E., M. I. M. E. With ninety-seven diagrams from original working drawings. Lon-

don: Cassell & Co. 1884.

This work, one of the manuals of technology edited by Professor Ayrton and Mr. R. Wormell, and published by Messrs. Cassell, is a comprehensive handbook of practical information, and of the scientific principles upon which the practice is based. We may at once state that Mr. Greenwood's book appears to us to be an excellent manual of the subject, which scarcely needs comment. The book is of service to the general student of the branch of technical science of which it treats, as well as to the intelligent workman, to whom it offers a succinct statement of the scientific principles upon which depends the success of the several processes in which he is engaged. The book

does not—and is not intended, we believe, to—supersede the experience and practical knowledge that can be gained only in the works; but it will be found a useful adjunct to, and contribute to a clearer understanding of, these things.—Iron.

THE MATERIALS OF ENGINEERING, IN THREE PARTS: PART III., NON-FERROUS METALS AND ALLOYS. By ROBERT H. THURSTON, Professor of Engineering, Stevens Institute, etc., etc. New York: John Wiley & Sons.

For this volume Professor Thurston goes very exhaustively into the history of non-ferrous metals and their alloys, giving their general characteristics and their special properties. The author's very extended and carefully conducted experiments have resulted in the composition of new brasses, kalchoids and bronzes which must be of special value to workers in alloys.

W ROUGHT IRON AND STEEL IN CONSTRUCTION. New York: John Wiley & Sons. Rules for Strength of Pencoyd Iron should be properly the title of this book. Rolling mills and bridge-building companies issue "Pocket Books" of "Useful Information for Engineers, &c.," which are not simply advertisements, but contain facts and tables very useful to engineers. Pencoyd is very slow in issuing its book, which, it must be confessed is below the aver-The book has the merit of age standard. being clearly printed on handsome paper. Pencoyd beams, channels, angles, and other shapes are set forth at great length. One might suppose that such shapes of iron had never existed before, and that a Pencoyd circle would contain a greater area than another circle of the same diameter. There is much theoretical matter in the book which is evidently very valuable in the eyes of the author, but the experiments published do not tell us what is of practical use, that is, for instance, what is the value of an angle iron, used as a strut or a tie, riveted by one leg only to its connections. The book is too shoppy and theoretical.

The Imaginary Metrological System of the Great Pyramid of Gizeh. By F. A. P. Barnard, LL. D., S. T. D. New York: John Wiley & Sons.

Dr. Barnard has rendered the public an excellent service in this essay. The advocates of the pyramid metrology are urging their claims in a way that tends to deceive those who are not sufficiently familiar with the fact that figures adroitly presented may be made very misleading. The honesty of the believers in the pyramid theories presented by Piazza Smyth is not to be questioned, but the theories arc, in consequence, all the more likely to deceive, and it needed the keen analysis and the pungent satire of the present volume to check the spread of this peculiar phase of fanaticism.

scarcely needs comment. The book is of service to the general student of the branch of technical science of which it treats, as well as to the intelligent workman, to whom it offers a succinct statement of the scientific principles upon which depends the success of the several processes in which he is engaged. The book

law of fanaticism that the faith of its subjects and victims is intense in proportion as its doctrines are defiant of common sense, it might reasonably have been expected that the wild conjectures, in regard to this monument, hazarded by John Taylor in 1859, would have fallen unnoticed from the press, and would long since have ceased to be remembered

among men."

These conjectures, which have been elaborated by Professor Smyth, and seriously formulated into a doctrine, affirm in general terms—that the Great Pyramid was built by Divine direction, and that its various dimensions reveal, when rightly interpreted, the size and density of our globe, the solar distance, and the length of the year; also exhibit quite accurately the periods of time separating the important crises

of sacred history.

As the length of the base of the pyramid affords the starting point for numerical comparison, and as there is a remarkable lack of agreement in the measures thus far obtained, Prof. Smyth has adopted a number lying between the extreme results, but which is not a fair average of the measurements, nor does it agree with any one of them, but it fits the theory, and is supposed to be, therefore, worthy of adoption. There is much of this kind of dealing with numbers among the pyramidists. Sometimes the measurement of the pyramid is made to adapt itself to the requirements of the theory, and sometimes it is the so-called revealed dimension or date that suffers the strain. An example of this latter kind is afforded in a proposition of Professor Smyth's, which runs as follows:

Mnltiply the tenth part of the cube of the ten millionth part of the earth's polar diameter by the mean density of the earth, and the product will give the pyramid unit of capacity. (The presumed original capacity of the sarcophagus.) Dr. Barnard says of this, after presenting the figures, "The arithmetical coincidence is exact; but we shall see that this extremely satisfactory result is only owing to the happy selection of a value for the axis of the earth, which no computer has ever found, and of a number expressive of the earth's density, which no investigator of that subject has ever reached."

Coincidences of like kind are numerons in the standard work of the pyramid followers (Our Inheritance in the Great Pyramid), and the principal ones are analyzed in like man-

ner.

If anything could exhibit the absurdity of the doctrine here criticised in a stronger light than the exposition of the method of establishing it, it is the satire embodied in Dr. Barnard's suggestion that a similar manipulation of figures exhibits the lunar theory in the temple of Ephesus, and the base of the hyperbolic system of logarithms in the base of the Great Pyramid.

Dr. Barnard's essay will be widely read, and most readers will learn with surprise that men eminent in science and literature have been misled by the doctrines that are therein so ef-

fectively analyzed.

DRAINAGE AND SEWERAGE OF DWELLINGS. By Wm. Paul Gerhard. 12mo., 302 pp. New York: Wm. T. Comstock. Price \$2.50.

It is always fortunate when a man eminently successful in a large practice is able and willing to write his views and methods clearly, and give them to the world in a book. Mr. Gerhard has made a book on an immensely important subject, which sustains the reputation he had before earned by his masterly report on this snbject to the Rhode Island Board of Health: We define a practical man to be one accustomed to successfully doing the work. Mr. Gerhard is now actively employed as chief engineer of a company making a speciality of draining honses and populous districts.

draining honses and populous districts.

It is not easy to find a polite descriptive adjective for the man or men who first ventured to take a privy into the middle of a first-class dwelling-house. Lazy is a weak term, and effeminate is a slander on the sex. His faith was strong—faith in the efficiency of water and traps which experience and the loss of many lives has shown to be misplaced unless more care and skill than usual are exercised.

This book by Mr. Gerhard seems to go far towards undoing the mischief. It does not, like too many, spend all the strength of the writer and the patience of the reader on the evils to be avoided, but diligently and patiently labors to show how to avoid them. It is liberally illustrated with sections showing the arrangements and devices in general view and in detail. Traps old and new are dissected profusely:

fusely.

We are particularly pleased with Chapter II., "Nccessity of Ventilation in Rooms containing Modern Conveniences," Chapter VIII., "Drainage of Cellars," and Chapter X., "System of Internal Sewerage as it should be in a Dwelling." The work should meet with an extensive sale.

A PRAOTICAL TREATISE ON ELECTRIC LIGHTING. By J. E. H. Gordon, B. A., M. S. T. E. Sampson Low, Marston, Searle

and Rivington, London. 1884.

It seems to us that the author of such a book as this should treat his subject under heads, his principal heads being: (1) generation; (2) distribution; (3) utilization, and (4) tools; the snb-heads may be as numerons as the author chooses. With regard to the generation of electricity little need be said of batteries; but some attempt might be made to explain the great similarity of the various dynamo machines. They are easily classed under a few types. The continuous ring armature type includes such as the Gramme, Burgin, Brush, Schuckurt, &c. Then we have the Siemens armature type, alternate current machines, and so on. Starting with a full and complete description of the typical machine, the various modifications, the reasons for their introduction and the gains by introduction could then be successively discussed. However, it is generally admitted that, according to their own showing, most reviewers would make ad-Unfortunately, when they mirable authors. attempt to carry into practice the views they put forward, the result is frequently a miserable failure. We shall therefore return to the real subject of this notice, showing that Mr. Gordon has, to some extent, carried out these views. After an introductory chapter on the

principles of artificial lightning, he shows the analogy between a fluid, such as water, and electricity. Although we think the way in which Mr. Gordon has introduced these analogies to be exceedingly instructive, we must not forget the caution of Clerk-Maxwell when warning his readers against the use of the term "electric fluid."

The aim of those who desire to produce artificial light economically is thus stated, p. 8, "to concentrate the heat in a solid of the smallest possible size, or with the smallest possible cooling surface." How this is done in electric light operations it is the business of the book to show. Whenever a new application of science is developed, it becomes necessary to show how the principles of the science are used in the development. Practical work needs systems for measurement, practical units of measurement, notation, and so on—a branch of the subject to which Mr. Gordon devotes some of the early chapters of his book. In these he discusses the relation of the electrical units with one another, and with the units of heat The electrician finds nothing new herein, but the electrical engineer will here see the arithmetic of his work. The formulæ he has to use are collected and illustrated. Here, too, are some interesting comparisons, showing the value of the commercial electrical unit in various measures, and we are given a rule for the comparison of the prices of electricity and gas. Thus: "To compare the price of electricity with that of gas, we must multiply the price per electrical unit by 10, and the result will be the price of a quantity of electricity approximately equal in illuminating power to 1,000 cubic feet of gas."

Electricity—to use an ordinary expressiongenerated for electric light purposes is utilized by means of lamps. The different incandescent lamps are, in the first place, described, and their method of manufacture, the details being given and amply illustrated. Then the best known types of arc lamps are described. requirements for the lighting of particular places are discussed, and it is shown how the lamps and other apparatus must be designed for the purpose in view. A very interesting chapter, for which the author states his indebtedness to Mr. Crompton, on carbons for arc lamps, is given, and then we come to that portion of the book dealing more directly with the generation of the current. Besides being a writer, Mr. Gordon is an inventor, and professes to follow the example of Cumberland, Maskelyne, and others, in "telling how it is done." We doubt, however, if the readers can invent, after reading this book, any more than the hearer could perform the tricks shown at St. James's Hall after hearing how they were done. Indeed, the telling is simply reduced to this: Mr. Gordon has by a process of reasoning come to the conclusion that a certain type of dynamo is the best, and he forthwith sets to work and designs such a dynamo. Now we are inclined to think that there is more than one road to travel in order to get to a new design of dynamo; and we are not at all sure that Mr. Gordon's explanation proves that his 131.66; l=.9, the electric force was 138.57, road is the best. However, there is no doubt that is, it began to rise again.

that he puts forth the principles of magnetic induction and of the best-known machines in a clear and concise manner. All this part of the book is exceptionally worthy of close study. It abounds with hints of a very practical nature, and points out what not to do in many

Before concluding this notice a word of praise should be given for the excellent illustrations and typography of the book.—Abstract of Review in Engineer.

MISCELLANEOUS.

THE riches of the United States from gold and silver mining may be partially estiand silver mining may be partially estimated by the fact that the aggregate production of gold up to June 30, 1883, has been 1,632,364,670 dols. That of silver has been 598,083,217 dols., making a grand total of 2,230,447,887 dols., or £446,089,577. Reduced to the equivalent weights, the total gold output has been 78,965,572 troy ounces, or 2707.4 avoirdupois net tons, while the silver weight represents 462,590,469 troy ounces, or 15,860 tons. Putting the statistics into another form, the gold produced in the country up to the present time, if brought together, would be sufficient to load 271 ordinary freight cars; the silver, supposed to be collected as fine bullion, would require 1586 cars for its transportation. The gold would tax the carrying capacity of a large ocean steamship, while the silver would form cargoes for a considerable fleet.

THE distances, often many miles, through which was is transmitted in the state of t which gas is transmitted before reaching an engine, are such that, with any other means of distributing power, they would considerably enhance the cost of the power. But in the case of gas, it does not appear that these distances are at all a matter of consideration. Professor Osborne Reynolds thus explains this:—It takes about ten cubic feet of gas to develop 1,000,-000 foot-pounds in a gas engine, whereas of air compressed in the ordinary way, it would require something like 140 cubic feet to yield the same power. Hence the comparative cost of transmission is the cost of transmitting ten cubic feet of gas against that of 140 cubic feet compressed air, and these would be about as one to twenty-five; so, as a means of distributing energy, gas is twenty-five times more efficient than compressed air.

Drofessor Foster recently read a paper, be-I fore the Physical Society, by himself and Mr. Pryson, on the difference of potential required to give sparks in air. Let V=this difference of potential, l=length of spark in centimeters, their experiments give approximately V=102l+7.07. Tables and curves of the sparking distances, potentials, and electric forces in the experiments were given. The results were got with brass balls 1.35 centimeters in diameter, a friction machine, and a Foster absolute electrometer. When l=142, the electric force giving a spark was 154.76; l=.284, the electric force was 133.35, or less than at a shorter distance; l=497, the electric force was

VAN NOSTRAND'S

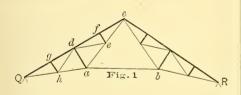
ENGINEERING MAGAZINE.

NO. CLXXXIX.—SEPTEMBER, 1884.—VOL. XXXI.

ANALYSIS OF A ROOF TRUSS.

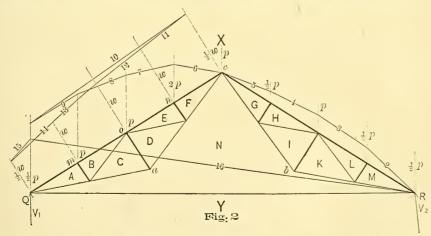
BY PROF. DEVOLSON WOOD.

Contributed to Van Nostrand's Engineering Magazine.



In the course of my instruction frames joins the lower ends of the long rafters. like Figs. 1 and 2, have occasionally been In Fig. 1, after finding the reactions of the supports, the analysis proceeds without difficulty until the joint a or d is reached, where three unknown stresses To pass these points various methods have been devised.

This frame is analyzed in the Graphical Statistics of Du Bois, and also in his later work—"Strains in Framed Structures;" and I remember seeing a solution, some analyzed graphically. It will be seen that the chief difference in these frames coning the following the seen that the chief difference in these frames coning the seen that the chief difference in these frames coning the seen that the seen sists in the position of the horizontal tie; a resort to a special artifice. In the two



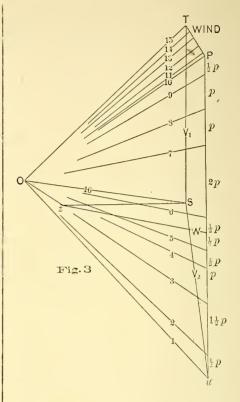
in Fig. 1 connecting the points α and b | former works, the stress on de due to the of the secondary truss, while in Fig. 2 it load at f is found, which reduces the un-Vol. XXXI.—No. 3—13

the analysis proceeds without difficulty. TPUST is the polygon of external forces. In Fig. 2, three unknown stresses meet at Q and R, so that the analysis of internal stresses cannot begin at these points unless the stress on the horizontal tie be first found. This frame may be analyzed by finding the stress on the secondary parts first, and thence passing to the primary parts; but we have generally sought the stress on the horizontal tie directly. Various methods were resorted to, until, at last, I conceived the idea of using the equilibrium polygon, for this purpose, which gave not only this stress, but also the stress at the apex c. I can hardly presume that this use of the equilibrium polygon is new, although I have no knowledge of its having been so used by others. The process is so distinct, and the results so satisfactory that we have used no other method since it was

For the purpose of illustrating and explaining the principle, I have assumed that the frame in Fig. 2 is loaded eccentrically, by weights $\frac{1}{2}$ p at Q, p at m, p at o, 2 p at n, p at c, and so on with $\frac{1}{2}$ p, p, $1\frac{1}{2}$ p, $\frac{1}{2}$ p, the last being at R; and also a wind pressure normal to Qc of $\frac{1}{2}$ w at Qand c, and w at each of the joints m, o, n. $n = \frac{1}{4}p = 1,000 \text{ lbs.}$

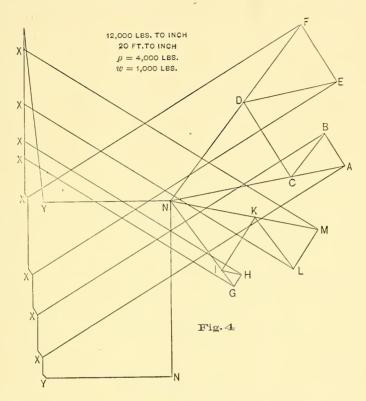
Assume that the frame is hinged at R and free at the support Q, then will the reaction at Q be vertical. In Fig. 3, construct a force polygon, or so much thereof as possible, with the known forces; TP for the wind pressures, PU the vertical weights, and a vertical through T to represent the reaction V, the length 7 which remains to be determined. From any assumed pole O, draw the radial lines in the well-known way, by means of which construct the equilibrium polygon in Fig. 2, beginning at R the point of application of the force V2, whose magnitude and direction are unknown. The radial line 1, Fig. 3, does not appear in Fig. 2, for it cuts V_2 and $\frac{1}{2}p$, both meeting at The other lines are numbered the same in both figures. The last line in Fig. 3 is 15, but in Fig. 2 the polygon must close, which is done by drawing 16, after which 16 in Fig. 3 is drawn parallel to that in Fig. 2. The line 16 in Fig. 2 cuts V₁ and V₂; hence S Fig. 3, where 16 cuts the vertical TS, is the common point

known stresses at d to two, after which will be V, in magnitude and direction.

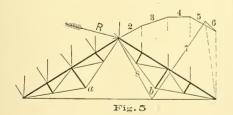


The magnitude and direction of the force at the joint c is unknown; to find which conceive a vertical plane passed through the point and the left half of the frame unmoved. Make, as before, as much of a polygon of forces as possible with the forces known as acting on the right half of the frame—which are $\frac{1}{2}$ p at c, then $\frac{1}{2}p$, p, $1\frac{1}{2}p\frac{1}{2}p$, which last is at R, and V_2 previously found. The several weights p are laid off from W to U Fig. 2, and US=V, as before found, and SZof undetermined length, horizontally through S will represent the direction of action of the stress in the horizontal tie. Using the same pole as before, construct an equilibrium polygon, beginning at c the point of application of the force whose magnitude and direction of action are unknown. In this case it so happens that the first equilibrium polygon passed through c so that the last named polygon will coincide with the former in part. It of V, and V₂; and TS will be V₁, and US will begin at c and end at R; hence the closing line of the polygon will be Rc, represent the stress in the tie RQ. The coincided with QR, and in Fig. 3 would

Had the pole O, Fig. 3, been taken at coinciding with the main rafter; and OZ Z, the equilibrium polygon, Fig. 2, would Fig. 3, parallel to Rc will intersect the horizontal force at Z, therefore ZS will Q so that the closing line 16 would have



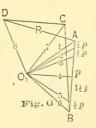
the frame will be WUSZW. Had the by one construction. other half been taken, the force polygon would have been TPWZST, or the same result would have been found.



Now the analysis of the other internal stresses may begin at Q,R, or c, and proceed in the usual way, the results of These are for the same problem as Fig. which are given in Fig. 4.

line ZW, joining Z and W, will represent have been ZS; in which case the stress the stress at c in magnitude and direc- in the tie QR, the oblique stress at c, and tion. The force polygon for this half of the two reactions would have been given

> If the first equilibrium polygon, starting at R, does not pass through c, it will be necessary to construct another. Figures 5 and 6 show such a construction.



2, but the scale of the figures are one-

Fig. 6. The line 8 of Fig. 5 is the clos- will give Fig. 4.

fourth the size. In Fig. 6, AB=WU of ing line of the polygon, parallel to which Fig. 3; BC=US; but the pole O, Fig. is 8 of Fig. 6, and the latter by its inter-6, is in a different relative position. The section with CD determines the point D. equilibrium polygon 2, 3, 4, 5, 6, 7, of Fig.

Then will DC=ZS of Fig 3, and DA=Z 5, corresponds with the pole diagram of W; and the remainder of the solution

ON THE ALTERATION OF MINERAL COAL BY EXPOSURE TO THE ATMOSPHERE, TOGETHER WITH A NEW METHOD TO PRESERVE IT.

By FRANZ POECH, ant. Mining Engineer, Vienna.

Translated by JOHN P. WISSER, First Lieutenant, First Artillery, U. S. Army.

(Oesterreichische Zeitchcrift für Berg- und- Hüttenwesen, May 31, 1884.)

especially the less compact lignites, holdgradually converted into rubbish and Bituminous coal is less liable to crumble, but loses by exposure in calorific power, and those varieties applicable for the production of coke lose the power of coking. Most mineral coals have a tendency to ignite spontaneously, and many a coal depôt has already been destroyed by this action.

An effectual method for the prevention of alteration and the spontaneous combustion of coal would therefore be of great value to coal producers, who are often compelled to store coal in enormous masses.

How sensibly the value of coal is dimished by long storage is shown by the

following example:

From a heap of stored Bohemian brown coal, medium coal I, which lay exposed 5 weeks, only 60 per cent. of this grade could be obtained in the re-sorting before shipping; the other 40 per cent. was converted into nut coal and dust.

The 40 per cent. removed by alteration lost in value 15 kreutzer* per hundredweight, from which the calculated loss for the entire quantity of stored coal amounts to 4.3 kr. per hundred-weight, the cost of re-sorting included.

The loss to coal works, caused in this way, is therefore considerable; a work in

It is well known that mineral coal, north-west Bohemia hardly makes 4.3 kr. per hundred-weight of coal. Moreover, ing much water, crumbles gradually by the loss increases in direct proportion to exposure to the air for some time, and the time of storage, and cases may be the finest and most valuable pieces are cited in which 80 to 90 per cent. of the coal deposited was altered by exposure.

Mining-Engineer Wenzel Poech, in Karbitz, has discovered a simple, cheap, and practicable means of preserving piles of coal. It consists principally in leading steam into the coal pile, thus excluding the air and moistening the coal uniformly.

Before proceeding to the description of the process I will discuss briefly the chemical and physical phenomena attending the alteration and spontaneous combustion of coal.

Porous bodies, it is well known, have the property of absorbing gases. This is seen in platinum sponge, which condenses so much air in its pores that the heat produced will cause hydrogen, directed against its surface, to combine with the oxygen and form water. It is also seen in charcoal, one of the most porous substances, representing, as it were, the skeleton of the wood mass. According to the experiments of Saussure, charcoal absorbs 9 times its volume of oxygen, and 35 times its volume of carbon dioxide.

Mineral coal also possesses a porous structure, and Saussure has shown that it absorbs three times its volume of oxygen.

According to Fayol,* the absorption

^{*1} Florin (Gulden) =100 kr., is now worth about 42 cents.

^{*} Comptes rendus de la société de l'industrie minérale, 1882, page 74.

power of all coal, from anthracite to lignite, is 5 to 10 per cent. by weight.

The property possessed by porous bodies of absorbing gases is a surface The walls of the pores attract the gases, just as water is drawn into narrow tubes. This has not been proven conclusively, but there is good ground for making the assumption; moreover, the hygroscopic power of a substance is taken as the measure of its absorbing power.f

While all other gases absorbed by coal remain unaltered, oxygen is condensed and combines with the carbon and hydro-

gen, producing heat.

Varentrapp t has shown that brown coal oxidizes in a current of air of less than 50° C. temperature, and that the amount of oxygen absorbed, although small, is nevertheless increased by an elevation of temperature, and may result in the complete consumption of the carbon

without producing ignition.

E. Richters & determined the fact that fresh, dry bituminous coal will absorb a considerable amount of oxygen in a few days, without giving off any carbon dioxide and water, and that these oxidation products remain condensed in the pores of the fuel. The latter circumstance offers no impediment to the absorption of oxygen, this only ceasing when the disposable hydrogen and the easily oxidized part of the carbon are combined with oxygen.

At normal temperature the absorption of oxygen proceeds until the complete oxidation of the easily oxidized constituents; hereby carbon dioxide may be given off, but at higher temperatures both carbon dioxide and water are driven

In case the absorption takes place slowly, so that the heat produced may be disseminated, and no appreciable rise in temperature results, hydrogen and oxygen remain condensed in the pores; only in the contrary case are they expelled, and new oxygen absorbed, new quantities of heat produced. Through the increase of temperature, however, an energetic chemical action takes place between the oxygen and the combustible material of

the coal, the result of which is finally spontaneous combustion.

Coal dust does not absorb more oxvgen than coarse granular coal, but the absorption, in consequence of the larger surface presented by the dust, proceeds much more rapidly, and herein, together with the difficulty of furnishing the coal dust with sufficient fresh air to carry away the heat, lies the cause of the more easy spontaneous combustion of coal dust.

According to Favol the temperature of ignition of lignite, in the form of powder, is 150° C., of anthracite, 300° C.

The causes of the crumbling of coal by exposure are manifold. In all probability it is due to the absorption of oxygen and the resulting carbon dioxide, which, being compressed, must exert a pressure on the walls of the pores. Possibly, also, by the chemical reactions, a body is disturbed which hitherto acted as cement.

Of great importance, directly or indirectly, in this connection is the circumstance that the hygroscopic moisture evaporates after a certain time, leaving the fine cracks and pores free for the penetration of the oxygen of the air, for which there is thus furnished a larger surface for its action.

Now, the escape of the hygroscopic water cannot take place without the production of mechanical alterations, as may be seen in the similar action of the warping of drying wood, or in the cracks of a dried swamp; hence the cracking and crumbling of stored coal through chemical action will be facilitated if the pores are first deprived of their protecting water.

A means which prevents the escape of the original mine moisture must be of the greatest benefit in preserving it. As will be shown more in detail further on, this can be accomplished in a simple manner by immersing the coal in water, or in an atmosphere of steam, since the mechanically held water will not escape in this case, and the passage of oxygen into the By keeping the coal pores be prevented. constantly moist or by steaming it, aside from the fact that the air is also externally excluded from the pieces of coal, the oxidation and alteration may be effectually opposed.

Brown coal loses little in calorific

[†] Dr. F. Muck, Grundzüge und Ziele der Steinkoh-len chemie, page 81. ‡ Johresberichte der chemie, 1865, page 837. § Johresberichte der chemie, 1869, page 1120.

power by crumbling, but considerable in commercial value. In bituminous coal, as a rule, the yield of coke in coking, and of gas in dry distillation, suffers considerable loss. Gas works prefer the newly-mined coal, as is quite natural, since the disposable hydrogen, so valuable in gas making, is the first to be oxidized by the absorbed oxygen.*

In regard to the part played by iron pyrite in the spontaneous combustion of coal, the following remarks may be made:

The view that only coals containing pyrite or marcasite are subject to spontaneous combustion, must be abandoned, since the observation has been continually made that often the coals free from pyrite have the greatest tendency to spontaneous combustion.

Fayol, who studied this question thoroughly and conducted careful experiments, remarks in this connection:

1. The first and greatest cause of spontaneous combustion is the absorption of oxygen by the coal.

2. The most favorable conditions for the self-heating of coal are a mixture of pieces and dust, an elevated temperature, a large mass of coal and a certain volume of air.

3. Large pieces, low temperature, small volume, and the complete absence of air or good ventilation, act in opposition to self-heating.

4. In general pyrite plays only an unimportant, mostly insignificant part in

spontaneous combustion.

5. Mechanical forces, or the heat produced thereby, cannot be assigned as the usual causes of the burning of coal mines.

Durand assumes that when the sinking roof of a gallery concentrates the entire pressure in a few places, considerable elevation of temperature may be thereby produced.

In order to investigate the effect of pyrite in elevating the temperature, Fayol carried out many experiments by placing pulverized coal, coal and pyrite in an air bath at 100° to 200° C., allowing them to remain some time, and observing the increase in weight and temperature.

He succeeded in showing that pyrite oxidizes less easily than coal (in the air bath at 100° C. the samples of coal took up 7 per cent. oxygen in three months, pyrite only 4 per cent.), and that the addition of pyrite to the coal even retards the increase in temperature. The results of the experiments of Fayol confirm the older work of Richters, but are less complete, in that they have reference only to the air-dried condition of the coal.

That the relation of pyritiferous coal to oxygen is different in presence and in absence of moisture, the experiments of Richters have conclusively proven.

This investigator found by direct experiment that pyritiferous coal, kept constantly moist, absorbs twice as much oxygen as in the dry state. The moisture accelerates the decomposition of the pyrite, and induces further chemical processes, such as the formation of salts, the absorption of water, etc., by which again heat is produced. In order that the moisture may cause this action a sufficient amount of oxygen is necessary.

Moisture, as a rule, rather retards than accelerates the production of heat, and only under peculiarly favorable conditions, and in presence of much pyrite and a sufficient volume of air is it capable

of promoting the alterations.

Hence, neither pyrite nor moisture nor mechanical power appears capable, in general, of causing the burning of mines, and, in by far the greatest number of cases, the cause of spontaneous combustion can only be found in the absorption of oxygen.

If the coal is placed in an atmosphere of water vapor, which excludes the atmospheric oxygen from the coal, the hygroscopic water will have no tendency to leave the pores of the coal, nor can a chemical action set in, even in presence of pyrite, the oxidation of which is, under other circumstances, essentially promoted by the presence of moisture.

It is therefore not to be doubted that, by displacing the oxygen and keeping the coal moist, alteration and spontaneous combustion may be checked. A complete immersion would meet the requirements, but would only be practicable in rare cases; irrigation alone would not be

perfectly successful.

Wenzel Poech excludes the air and produces a uniform wetting of the stored

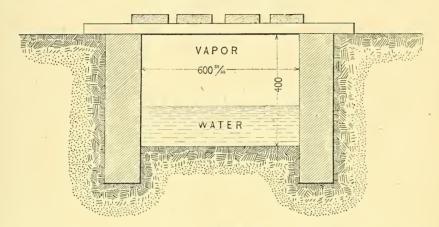
^{*} The "Journal fur Gasbelenchtung und Wasserversorgung," 1:84, page 232, cites a case in the Nettlesworth coal, which, after six months' storage, had crumbled to dust. The yield of gas fell from 29 m³ to

admitting spent steam into the depôt

For this purpose a series of trenches equal to 3 m. is 3 m. are cut in the depôt ground, as shown in cross section here; they are so covered with beams and boards that narrow mit the coal to fall through.

piles of coal, as already mentioned, by coal to be stored and the height of the pile; for medium-sized coal the distance between the canals, with a height of pile

The exhaust steam of a steam-engine of 4e, which was worked for but six hours during the day, was entirely sufficient for spaces remain, not large enough to per- the preservation of a depot of 20 carloads of coal.



The boards are simply laid on cross pieces, are not fastened, and can be easily removed for the purpose of cleaning out the trenches.

On the ground thus prepared the coal to be stored is deposited in the usual way, the trenches are then connected with the exhaust-pipe of a steam-engine, and the steam admitted; it passes through the interstices in the covering into the coal pile, disseminates itself through the latter, displaces the air, and in consequence of the condensation of the vapor moistens the coal uniformly.

In order to effect a uniform distribution of the vapor it is necessary to cover the coal depot with fine coal and cinders, as in the case of charcoal heaps; thereby strong draughts of air will also be prevented from passing through the pile and interfering with the equal distribution of the steam. In case of coal containing little pyrite, careful covering of the pile is not so necessary, but is of importance in case of coal rich in pyrite.*

The width of mesh of the network of canals which exists in large depot grounds depends upon the size of the pieces of

In carrying out the process it was repeatedly shown that the losses sustained in the purely mechanical movements, in the pouring out at the unloading of the coal, are far smaller than they are usually assumed to be, and that in this assumption a large portion of the waste produced by alteration was attributed to the destruction by the pouring out.

In the loading of the coal preserved by steam it was found invariably that only in the locality where the first unloading took place, and where the coal fell from greater heights, attrition took place, the rest of the coal was good, was well preserved, and could be loaded without re-sorting.

The cost of construction of the trenches and their coverings—for which latter old and otherwise useless boards, beams and road-beams of the mine are utilized for a depot for 100 car-loads of coal amounts, at most, to 30 florins.

The cost of working is nothing, and the outlay consists only of the cost of preserving the trenches, and the interest and amortization on the applied capital.

Results relative to the use of this process have been obtained at the following works:

^{*}This should be confirmed by determining first whether the covering of the pile, by preventing the escape of the heat developed by the condensation, may not be harmful.

tonia" shaft, near Karbitz.

"Ferdinand" shaft, near Teplitz.

"Bruno" mine, in Weisskerchlitz, near Teplitz.

At the Maria Antonia shaft, in consequence of the thankworthy permission and support of "Bergdirector" J. Neuber, the manager, Wenzel Poech was enabled to make the first experiments, and conclusions: since then the process has been in full working order.

the Austrian Coal Industry Association, confirmation of the described preservation method was quite accidentally found: over a reservoir, covered with debris, and into which exhaust steam passed, coal had been deposited, which, on reloading

According to communications from mining engineer Hans Gutmann further experiments were carried on with favorable results, and the working of the process on a larger scale was proposed.

it, was found to be perfectly preserved.

The Director of the Bruno Mine, Em. Baier, uses old gratings to cover the in no way altered.

To insure a uniform production, and be regarded as perfectly passive, and with reference to the increasing losses at may even be detrimental to the warming. the works, it is much to be desired that cessful, especially as the methods formerly used proved worthless.

"Exc. gräflich Nostiz'scher Maria An- pile is directly detrimental, since oxidation is thereby only favored; investigation has also shown that at the surfaces of contact between the walls of the tubes and the coal, the latter is most liable to spontaneous combustion, so that now, on the contrary, the tendency is to level the coal as compactly as possible.

I arrive, therefore, at the following

Freshly-mined coal, deposited on the rubbish piles is capable of condensing sev-At the Ferdinand shaft, belonging to eral times its volume of oxygen in its pores. The oxygen absorbed enters into chemical combination with the easily oxidized constituents.

> According as the absorption is rapid or slow, a greater or less elevation of temperature is produced. In the former it may lead to spontaneous combustion.

> The crumbling of coal is, among other causes, a consequence of the absorption and condensation of oxygen in its pores, and the chemical changes taking place. The escape of the hygroscopic moisture favors the absorption of oxygen.

The pyrites can only produce a furcanal; he also subjected coal, without thersome effect on the increase of tempercovering with cinders, for more than two ature when present in considerable quanmonths to exhaust steam, and found it tities, and then only in presence of moisture and air; in the dry state they must

Freshly-mined coal placed in an atmosthis process may prove completely suc-phere of steam can suffer no change. Even with incomplete exclusion of the air the steam will, in general, oppose The usual insertion of wooden tubes oxidation and warming, principally by and the production of canals in the coal uniform moistening of the pieces of coal.

THE CONSTRUCTION OF IRON VESSELS.

From "Iron."

Lane, by Mr. S. J. Mackie, C. E.

Trade, the shipowners, the shipbuilders, absence of responsibility by compliance

THE following paper, on "The Con- and the mariners, can we rise from the struction of Iron Vessels and the Board contemplation and feel that the roots of of Trade Rules in regard to the Safety the evil have been really reached? Or, of Ships and the New Shipping Bill," that the responsibilities tried to be was read on May 8, at the Inventors' In thrown on shipowners are such as ought stitute, Lonsdale Chambers, 27 Chancery not to be properly shared at least by the Board of Trade? The position of ship-If we regard the whole of the contro- owners with regard to governmental conversies which have been so hotly waged trol ought to be either entire responsibetween the President of the Board of bility within well-defined limits, or entire

with governmental requirements. What-bined action tending to increase the gash ever the shipbuilders have done amiss, fact, in this case of safety of ships at sea, offered a distinct premium for the building and sending to sea of unsafe and un-Trade revise and alter its own rules, and there will be little need for other legislation. It will not be in the interest of shipowners to own dangerous vessels, if they can get safe ones to be built upon anything like equal terms. The severe inequality of the existing terms are solely due to the rules of the Board of Trade. There are points to be brought out. What really is the condition in which we find the ships of our mercantile marine? Look at the newspapers from day to day under the heading of "Wrecks and Casualties," and for the various accounts of vessels run down in collisions or broken up on going ashore, or capsized from shifting of cargo! Ought an iron vessel to go to pieces when she goes ashore? Or, if properly constructed, ought she not to rest there, and resist the battering of winds and waves until a high tide admits of her release? Ought an iron ship to sink in so few minutes after a collision on the broadside that there is not time to rescue even her crew—still less time to rescue her passengers if she carries any? Ought any sailing ship to capsize if properly designed? Ought a steamer's shaft ever to break by twisting, or engine bearing ever to get hot, as they frequently do, through the strains of a badly constructed These are questions which a hull? knowledge of existing inventions would speedily reply to, and are conditions which, if required to be fulfilled, inventors would quickly answer! Let us go no see river steamers built to the requireweight of the engine in it, and only \(\frac{1}{4}\)-in. man as the best architect who could proends would cause upward pulls, the com- architect has almost disappeared.

and to pull the hull asunder. Is this a the Board of Trade has done worse! In fit vessel to carry passengers by the hundred on a river busy with tidal, steam, safe ships from being designed, and have "Certainly not." But the Board of Offered a distinct promise for the latter of the latt Trade sanctions such steamers, not only for the river, calm and smooth, but for trustworthy ones. Let the Board of service on the boisterous seas! Does anyone conceive that the surveyors of the Board of Trade don't know such vessels to be unsafe? Assuredly they must know it; but will the Board of Trade permit the interference of its officers? The Board of Trade declines responsibility, but it does not decline to enforce its antiquated rules upon the designers of ships—rules neither founded on arithmetic nor honesty, but which fudge the tonnage of the ship, and risk the sailors' lives, to save the owners' pockets in dues to be paid? Are not harbors and lighthouses, whether English or foreign, worthy of their tolls for their services to shipping without being cheated of their dues by rules of measurement, which give dangerous vessels the advantage over safe ones? These rules have been handed down from our grandfathers, who had wooden vessels, and kept the carrying trade of the world in their hands. So it is that still, by the breadth and half breadth and other complications, the Board of Trade rules bring about the calculated result, that a rectangular box swum one way in the water will carry more upon the same displacement of water, than it will if swum the other way —which is nonsense. In the olden time it gave the shipowner a governmental certificate far below the carrying capacity of his vessel, and consequently his ship's dues were less than they ought to be whenever he had to pay them. These rules do the same thing now for the further than the Thames, and we shall modern iron ships and the modern shipowner. But note what has been the efments of the Board of Trade, and ap- fect of these rules upon the naval archiproved by surveyors, having the middle tect, the designer, and the contractor! body entirely undivided, with all the dead The ancient shipowner regarded that iron skin to keep out the water! Such a duce a sea-going vessel which could vessel being hit amidships, what would carry her cargo best on the same tonbe the result? We know it by the nage measurement by Board of Traue Princess Alice. The dead weight of the rules. Hence we have in the stated deengines and boilers would tend by grav-tails of vessels, "tonnage registered" as itation to sink; but the buoyancy of the distinct from "displacement." The naval

builders have become ship designers, and the same dead weight of cargo carried cheap ships have become as cheap houses. Ithan narrow ones, and consequently they Shipowners think most of the firm who can get into tidal harbors, and estuaries, can get most cargo into a ship of the and rivers where deep-draught vessels same registered tonnage. It is only to cannot go. Breadth of beam has also know what is the fundamental principle similar advantages in ships with sail and of this dodge to comprehend at once steam power. But breadth of beam is how its the worst sailing and the worst steam vessels, as well as the most is charged for dues by the registered dangerous, the more fully it is employed and carried out. There is no be stowed. But breadth of beam-at form of vessel or receptacle that will any rate, properly proportionate breadth carry more than a square box. Hence of beam—is essential to the designer, if the direct outcome of the Board of Trade he is to give proper outline and form to rules is the square midships section. his vessel. Now, floated in the water there is no form more unstable. It capsizes naturally, and load it uniformly, or how you will, the tendency to capsize is always there. It is innate, and can never be got The square midship section, then, is the dodge—the instability of the ship is the result. The old wooden vessels had a reserve of buoyancy in the thickness and lightness of the material of which they were constructed, and waterlogged wrecks were not uncommon. There are no waterlogged iron, singleskinned vessels, and one reason why steel is preferred to iron is that that material can be prepared thinner and lighter, and so add to the carrying capacity of the hull. But the thinness of the material adds also to the danger of those on board, who have to traverse the seas in sailing vessels. Sailing ships have to be varied in depth in proportion to the sails they carry. The sailing ship practically is a pendulum, the weight upon the bottom of the hull bringing the sails upon the mast against the pressure of the winds. The sailing ship, therefore, must cleave the water as she passes Not so the steamer; the through it. steam engines make it independent of the winds, and its contained motive power can propel it, if not entirely, at any rate to a large degree, over the water, instead of through it. If sail and steam power are combined, the requirements in the form of the hull will have to be modified accordingly. The proper fundamental condition for steamers is breadth of beam. Broader steamers of the same bulk will founder, even if cut in two! ones, will have less draught of water for more dues to pay than he ought to do,

application must produce worse than prohibited by the Board of Trade rules. It is absolutely fined! It tonnage, for more tons than can actually He cannot bring out the best, the easiest, the steadiest, fastest, safest, and most seaworthy and stable form of hull without being as unlimited in the scope of breadth as he is in the scope of length. Neither can be bring out all the good qualities of hull if he be restricted in the application of mechanical principles, or in mode of arrange-All these are completely indement. pendent, except under Board of Trade rules, of the proper requirements for tonnage measurement. All that the Board of Trade ought to do is to ascertain that there is buoyancy enough in the particular ship to be registered for her to carry a given weight of cargo upon a given load-line—in other words, that the cargo-carrying capacity shall be estimated by displacement. Thus, say that a thousand tons of cargo, whether in bulk or dead weight, shall be taken on a thousand tons displacement of water, and that the load-line should be fixed and written on the register at this point. another way: the vessel, when light, draws, say, ten feet of water, it is easy to calculate that with a thousand tons' weight of cargo on board she will draw, say, 20 feet of water. Her load-line should be marked at 20 feet and her registered tonnage certified at 1,000 Do this, and the naval architect tons. can do his very best, and the shipowner will be able to buy a safe ship for almost the price of a dangerous one. He will then pay any small extra cost, as he will save it in insurances at diminished rates, as he can have a vessel which cannot He will steam faster than narrow ones. Broader have an easier ship, a faster ship, one steamers will be more stable than narrow that cannot capsize, and he will have no

of wooden sailing-ship builders. Hence lisions. remaining in iron ships. The old leaven steamers alike. The practice of the shipbuilders designing their own ships is a grave barrier to progress in the general improvement of iron vessels. The shipbuilder now generally builds the engines also, and consequently there has arisen theory that the form of the vessel has nothing to do with the speed, and hence we are told that "you can drive any form of vessel at any speed you like, only you must put in the horse-power, and pay for it."

What, then, are the essential requirements for an ideal proper iron ship? (1) the hull by bulkheads, both transverse and longitudinal. (3) Buoyancy sufficient to float the vessel with its cargo properly, and enough to spare as a reserve to prevent the vessel sinking under any

and which it is right and proper and the assumption of this particular recti-honest that he should pay. The accom-lineal form. This is easily accomplished, modation for passengers on this ship and to any extent required, by the dispowill be better than on a narrow one sion of the transverse bulkheads with an The stowage of cargo will be better, and iron deck and the introduction of two the lives of the captain and his crew will longitudinal girders. By rising the kelbe unimperiled by any of the needless lon internally the box girder chambers, and terrible dangers brought about by into which the interior of the hull is thus the senseless rules of the Board of converted, is supported for its whole Trade, and its still further objectionable length, and in this way an end-on-end proceedings of allowing the owner to fix strength is imparted to the ship as his own load-line disc where he pleases should bear her harmless from serious efupon the ship. The introduction of iron fects from end-on-end encounters. The into shipbuilding has been effected by longitudinal girders would be of even far men who were imbued with the notions more importance against broadside col-We have seen the Arona trathe semblance of carpenters' work still verse the ocean for hundreds of miles with her bows stove in by collision with leavens the mass, sailing ships and an iceberg which would not get out of the way; and we have read of the Vanguard going down in fine weather and in broad daylight from a tap amidships. Amongst merchant vessels, with scarcely any exceptions, iron vessels of all classes go down after broadside collision so suddenthe convenient but not incontrovertible by that only a few out of the many on board are saved, even when brave hearts and willing hands are ready to do any deed of daring if but a few minutes of precious time were permitted for the exercise of their courage and their help. By the combination of longitudinal and transverse bulkheads, only one or two local compartments, external to the main Strength, combined with lightness of and vital interior box girder chamber of construction. (2) Safety, by division of the ship, would be filled with water in the most severe collisions, and the sinking of vessels from broadside collisions would be thus eliminated from the category of the serious dangers of the sea. The introduction of longitudinal girders amount of damage she may receive would prevent any dangerous shifting of afloat. (4) Rigidity in the construction cargoes, and would also—under a proper of the hull, so that there shall not be Board of Trade system of registration contortions and vibrations of its frames for dead weight of cargo to be carried and structure, and that the bearings of a sufficient reserve amount of buovancy, the engines and shaft shall not be subject reserved, too, in the right places, as to strains detrimental to the working of should, under every circumstance, prethe engines. (5) Proper design of ship, serve the vessel from sinking. Such so that the vessels shall have the best spaces of reserved buoyancy should not qualities of easiness, stability, and exter- be legally used for cargo. They would nal form. Seeing the weakness of exist- not remove or take away from the buoying vessels, it is clear that the longitu- ancy ordinarily in action for the flotation dinal strengthening of the ordinary hull of the ship and its cargo, but they would is a most vital matter. Regarding the come into action when, and only when, box girder as the strongest form of iron the ordinary buoyancy was interfered construction, I have always advocated as with, whether by intake of water by the fundamental basis of an iron ship breach of the skin of the ship, or by

the heeling over of the vessel from sail power, or from any other cause. Then the reserved spaces would exert a righting influence automatically, and in direct proportion to requirement. Some of the practical officers of the Board of Trade have personally recognized the value of this system of designs which I have unofficially submitted to them, as also have various officers of the great insurance companies. Some of the most eminent of our best shipbuilders have also been willing to contract for building such vessels as against estimated price, and to take the risk upon themselves of repayment of cost as against very high speed to be realized. But how could the invention progress when the shipowner was subject to loss under the Board of Trade rules for every improvement which he was asked to make, and which, it is true, added something to the cost of the construction of the ship. Even the total extra cost was in some measure due to the unalterable requirements of the Board of Trade, which prevented their surveyors from passing vessels for classification with an external skin of less than a certain thickness, and which thickness might be right in regard to single-skin ships of ordinary construction, where the main strength of the ship is in the skin; to vessels constructed with an internal box girder chamber, constituting an independent citadel of strength and safety, not to be compromised by the damage or even total loss of the outworks. Board of Trade have already, on the application of Messrs. Denny, of Dumbarton, eliminated the double bottom from measurement for the registered tonnage; why not go the whole length further and eliminate buoyancy spaces?

Whilst vessels are measured from outside to outside, and the whole cubic contents calculated by the existing rules of the Board of Trade, so long will the rectangular midship section of hull be adopted by shipowners. But it is, as has been said, an unstable form, and water ballast is required to keep the vessel from turn-The more dead weight cargo ing over. that is put in, the better for the stability; but it is the reverse with homogeneous or bulky cargoes, such as grain, cotton, and so forth. If, after the cargo

is brought out of the water by pumping out the water ballast, the instability of the ship is increased. If double sides be permitted to be exempt from tonnage measurement, their adoption by shipowners will be advantageous to them. If the concession of eliminating the double bottoms was right—and it was right—then the first concession should be followed and longitudinal side spaces should be conceded also. By taking the actual load-line of a vessel as representing the displacement of water by actual weight of cargo, no vessel with an improper cargo on board could go to sea unobserved, and the pranks which are played with the Plimsoil load-line at this time would be no longer practicable. The dodges played by shipowners between double bottoms and water ballast and cargoes only require to be made intelligible for the public to understand how valueless, in regard to the safety of our sailors, as well as our ships, have been the ways and doings of our Board of Trade, how utterly inadequate has been the legislation on the subject, and how profoundly ignored by Parliament have been the fundamental scientific principles which govern the vital subjects of naval architecture, shipbuilding, speed, safety, and loading. One of the missions of the Inventors' but which rules are clearly inapplicable Institute, it seems to me, should be to watch over discussions of such national importance, and in such cases to bring under the attention of the public and of the legislature the scientific principles involved, and to demonstrate the general practical bearings of existing inventions.

A T a recent meeting of the Philadelphia Engineers' Club, President Ludlow described tests of the crushing strength of ice, which were made by him in order to learn approximately the strength required for an ice harbor of iron screw-piles, in mid-channel, at the head of Delaware Bay. Eighteen pieces were tried with Government testing machines at Frankford, Philadelphia, and at Fort Compkins, Staten Island. The specimens were carefully prepared 6in. and 12in. cubes, and roughly cut slabs about 3in. thick, of different qualities and from different localities. For pure Kennebec ice, the lowest strength obtained was 327 lbs., and the highest 1,000 lbs. per square inch. For inferior qualities, the strengths varied from 235 lbs. to 917 lbs. The higher results were obtained, generally when the air temperature in the testing room was from 29 deg. to 36 deg. Fah., as against from 55 deg. to 68 deg. Fah. for the lower results. The pieces generally is taken in, the load-line of the ship compressed from in. to lin. before crushing.

EXPERIMENTS ON THE PASSAGE OF ELECTRICITY THROUGH GASES—SKETCH OF A THEORY.*

BY ARTHUR SCHUSTER, Ph.D., F.R.S.

From "Nature."

THE passage of electricity through tongue projects from the end of the posiof importance to see whether these facts throw any light on the theoretical notions which we have based on other branches

of electrical inquiry.

electrical potential separated by a layer of air, we might imagine the air in contact with the bodies to become electrified, then move on, impelled by the electric forces, and re-establish equilibrium by giving up their charges. The passage of electricity through gases would then be similar to the diffusion of heat. But, however natural such a view would be, it is impossible to maintain it in the face of experimental facts. The experiments which I shall bring before you to-day seem to me to support, on the contrary, the idea that the passage of electricity through a gas resembles the phenomenon studied by Helmholtz under the name of electrolytic convection.

I shall avoid as much as possible all suppositions and hypotheses which cannot be put to the test of experiment; but it seems necessary to start with some assumption in order to avoid too great a vagueness in the subsequent explana-The assumption which I shall make is this: In a gas the passage of electricity from one molecule to another is always accompanied by an interchange of the atoms composing the molecule. shall also try to prove that many facts are easily explained by the assumption that the molecules are broken up at the nega-

tive pole.

If, in a vacuum-tube of the ordinary form, the discharge is passed at a pressure of about one millimeter, a luminosity is seen round the negative pole which is called the negative glow. A luminous

gases has of late years become a very tive pole, which I shall call the positive favorite subject for experimental investi- part of the discharge, without meaning A large number of facts have to imply that it is charged with positive thus been accumulated, and it becomes electricity. The positive part of the discharge and the negative glow are separated by a non-luminous space, which I shall call "the dark interval." The glow itself is divided into three layers, the If we have two bodies at a different thickness of which increases with decreasing density. Closely surrounding the electrode itself, we have in the first place a luminous layer, which on new electrodes is of a golden color. The spectroscope shows the presence of sodium and hydrogen; the sodium is due to foreign matter deposited on the electrode, and the hydrogen is expelled by the action of the heat out of the electrode by which it had been absorbed. When the electrodes have been in use for some time, the golden color disappears, and the spectrum belonging to the gas used is seen. The second layer is known by the name of the dark space. The third layer is the glow proper.

> The theory which I shall endeavor to establish is this: That within the first layer the gaseous molecules are decomposed, that their negative parts are projected with great velocity through the dark space, that this velocity is gradually reduced by impacts within the glow, and that in the positive part of discharge the discharge takes place by diffusion except when stratifications appear.

> According to the kinetic theory of gases, the molecule of mercury vapor consists of a single atom, which is incapable of vibration. Mercury has a very brilliant spectrum, which proves that the theory is incomplete in some important point. It is well known, on the other hand, that the theoretical conclusion receives support from the fact that the vapor-density of mercury vapor is anomalous. If, as is generally supposed, the molecule of the majority of gases contains two atoms, that of mercury can only con-

^{*} Abstract of the Bakerian lecture. Read before the Royal Society.

tain one. If an essential part of the glow produce a finite difference of potential at vapor to present other and much simpler phenomena than the gases with which we are generally accustomed to work. This, indeed, is the case; for I find that, if the mercury vapor is sufficiently free from air, the discharge through it shows no negative glow, no dark spaces, and no stratifications. At the ordinary temperature the spark does not pass through mercury vapor, but if a tube free of air, but containing mercury vapor, is heated, the discharge passes always in a continuous stream of light. It is not always quite symmetrical with respect to the two poles; and a very curious tendency of the spark is noticed, to pass at the negative the electrode protrudes than from the metallic electrode itself. A brilliant sodium spectrum then appears at the point from which the spark sets out. Whenever small traces of air remain, stratifications are very apt to appear, as a mixture of air and mercury gives fine stratifications, but I have never noticed them after sufficient removal of the air.

I now pass to the description of an experiment which seems to me to be only capable of explanation by the views brought forward in this paper, and I should like therefore to consider them as shall assume the whole electrode to be of crucial experiments, which have to be explained by any true theory of the dis- will then cut the surface at right angles, charge. As negative electrode, I use an and could we assume the condenser to be aluminum cylinder of 5.5 cm. internal diameter and 8 cm. long. A long aluminum mal force acting on its particles; but as wire running parallel to the axis of the the lines of force are curved, the particles cylinder at a distance of about an inch not in immediate contact with the surface formed the positive electrode. On ex- are acted on by a tangential force which haustion, the discharge at first passes as will tend to drive them away from the a spark in the ordinary way, but as the positive electrode. As a steady state will pressure decreases the glow gradually only be possible when the total force is surrounds the whole cylinder, with the normal throughout the condenser, we arexception of a dark strip about 2 or 3 cm. rive at the condition for the steady state in width, directly opposite the positive that within the condenser the fall of powire. The positive electrode seems, there-tential must be the same for equal disfore, to repel the negative glow.

The following seems to me a plausible surface. explanation of the phenomenon which I

discharge is due to the breaking up of the electrode, while a double layer will the molecules, we might expect mercury produce a discontinuity. Although it may not be proved that an absolute discontinuity of potential exists at the kathode, it is yet certain that a very rapid fall occurs at that place. This is all that is

necessary for the argument.

We recognize such a double layer in the case of electrolytes, but there is an essential difference in the thickness of the layer within which we must imagine that condenser action to take place. In the liquids that thickness must be very small, as is shown by the intensity of the observed polarization currents The positively electrified matter in every case is kept against the negative surface by a joint action of electrical and chemical pole rather from the glass out of which forces, for it has been shown by Helmholtz that only thus can we explain a difference of potential between two bodies. It is the chemical forces which keep the electricities asunder. The gaseous molecules or atoms, however subject to their mutual encounters, and always having certain velocities, will tend to leave the surface. They are kept near the surface, however, by the electrical forces.

> Suppose, now, that a positive electrode is placed near such a condenser. The resistance of the gas is so much greater than that of the metal electrode that we the same potential. The lines of force infinitely thin, there would only be a nortances measured along the normal to the

Experimental evidence speaks strongly have just described. The rapid fall of in favor of such a conclusion. If, for potential which is observed on crossing instance, a thin wire is used as electrode, the negative electrode suggests at once, it is well known that the tension at the independently of any theory that we have end of the wire before discharge is very to deal with, the action of a condenser, much larger than anywhere else. At high for we know that no statical charge can pressures the discharge passes indeed from the end of the wire, but as the exhaustion proceeds, the glow gradually covers the whole wire, and the same amount of electricity flows out of equal areas situated anywhere on the wire, for the dark space which alters its width with the intensity of current is everywhere the same; this implies that the fall of potential per unit distance is the same all over the wire.

Hitherto we have only assumed a certain number of particles positively electrified in the immediate neighborhood of the negative electrode, and we have left it altogether undecided what these particles are. But if we consider now the fact that the glow does not appear opposite the positive electrode, that is to say, that while the the fall of potential is the same all over the surface the flow is stronger at some places than at others, we are driven to the conclusion that the flow does not altogether depend on the fall of potential, and we must again look for an explanation in the chemical as well as the electric forces. Wherever the fall of potential is chiefly produced by the presence of the positively electrified particle, which I now assume to be the decomposed molecules of the gas, these will help by their chemical action to decompose other Opposite the positive pole molecules. the fall of potential is principally due to nearness of that electrode; chemical forces are absent, and the molecules will not be decomposed. This is, I believe, the explanation of the dark area. And it brings with it the explanation of a large quantity of other facts, as, for instance, the one which has been so long observed and well established, that once a current is set up in the gas it requires a much smaller electromotive force to keep it going. For the discharge, according to us, will generally be introduced by a spark which must give the first supply of decomposed molecules before the continuous glow discharge can establish itself.

I may for the sake of clearness once more mention shortly the principal points of the argument.

The rapid fall of potential in the neighborhood of the negative electrode renders the presence of positively electrified particles in its neighborhood necessary.

If the distance through which the condark space forms the negative electrode. denser action takes place is sensible, the If the dark space is small and does not

positively electrified particles will be acted upon by a neighboring positive electrode.

A steady state will be established in

A steady state will be established in which the fall of potential along the normal from the surface will be everywhere the same.

As, however, the flow is stronger away from the positive electrode, we must conclude that other forces besides electrical forces determine the flow.

It is natural to assume that these are chemical forces: that, in other words, the positively electrified particles are the decomposed molecules, which by their presence assist the decomposition of others, and therefore the formation of the current.

Unless a flaw is detected in this line of argument, I think that the conclusion must be granted, namely, that the decomposition of the molecules at the negative electrode is essential to the formation of the glow discharge. This is really all that I endeavor to support in this paper. The rest can only be settled by further experiments. And amongst the rest I count also the primary cause which originally produces the decomposition of molecules at one pole rather than at another. It is possibly due to an electromotive force of contact between the gas and the electrodes which tends to make

the gas electro-negative.

The gaseous molecules, then, according to our theory, are decomposed at the negative pole. Their negative constituents can follow the electric action, and as the fall of potential in the immediate neighborhood of the pole is very rapid, the atoms will leave the pole with considerable velocity. That the region of the dark space is filled with matter projected from the negative pole follows almost conclusively from the experiments of Goldstein and Crookes, and is also shown in a most striking way by an experiment due to Hittorf. If a tube contains two parallel wire electrodes at a distance of. say, a quarter of an inch, the discharge will at high pressure pass in the usual way from electrode to electrode, but at very low pressures the discharge from the positive pole goes away from the negative. The results can be shortly expressed by saying that, as far as the positive pole is concerned, the inner boundary of the dark space forms the negative electrode. passes from the latter towards the negative pole, but as soon as the dark space extends beyond the positive pole, the positive part of the discharge goes towards the nearest point of the dark space that is straight away from the negative

pole.

We have then two closely adjoining, almost overlapping, parts, in which the discharge is in opposite directions, and this could not be unless electricity is carried by matter which can, owing to its inertia and high velocity, move against the electric forces. To my mind this experiment proves conclusively that the negative electricity is bound to matter projected with high velocity away from

the negative pole.

Goldstein has shown when a thin pencil of the negative glow belonging to one electrode passes close to another the pencil is deflected. According to our view, such a pencil would be formed by a succession of negatively charged particles projected in nearly the same direction away from the negative electrode; as these particles pass by another kathode, they are naturally deflected out of their path by the electric forces. stein has shown that if the current is equally divided between the two kathodes, the deflection is independent of the intensity of the current, the pressure, and the nature of the gas. This is exactly what ought to happen according to our theory, for strengthening the current at one kathode means, as will presently appear, increasing the velocity of the particles. The square of the velocity will increase in the same ratio as the total fall of the potential in the neighborhood of the negative pole; as the particles pass the other kathode, the forces from it are increased in the same ratio as the square of the velocity with which they are moving, and consequently the path will remain the same. Similarly all the other experimental facts established by Goldstein can be easily explained.

The most conclusive proof of the view adopted in this paper would be found in the demonstration that the amount of electricity carried by each particle was always the same, whatever the current. I propose to test this fact in the following way:—It was found by Hittorf that

reach to the positive pole, the discharge tive electrode, and projected at right angles to the lines of force in a magnetic field are bent round in a circle. This is as it should be, and I calculate that the radius of the circle ought to vary as $\sqrt{F/e}$, where F is the total fall of potential within the region in which the particles acquire their velocity, and e is the amount of electricity carried by each par-As the current increases, it is shown by Hittorf that F increases; and I find that at the same time the diameter of the ring in the magnetic field increases. If this diameter varies as the square root of F, it would be proved that e must be constant as it is in electrolysis. At present we can only say that the average amount of electricity carried by the particles must increase less rapidly than the fall of potential. If e varies at all, we should expect it to vary proportionally to the fall of potential in the neighborhood of the negative electrode, and in that case the diameter of the ring would be independent of the current, which it is not.

The theory which I advocate involves the existence of a polarization, and it might be considered a difficulty that no polarization currents have with certainty been observed in gases. I believe the difficulty only to be apparent, for the experiments prove that the fall of potential near the negative pole, though rapid, is not sudden, so that the layer within which the condenser action takes place is very much thicker in gases than in liquids. The capacity of the condenser is therefore smaller, and though the total fall of potential in the gas may even be stronger than in the liquid, the polarization currents might escape observation.

With regard to the positive part of the discharge it will be sufficient here to mention that stratifications are principally observed in mixtures of gases or in compound gases, and that in the intervals between two stratifications the discharge is very likely carried as through the dark space at the negative electrode, while in the stratifications re-combination of the decomposed atoms takes place.

An interesting law has been proved by Hittorf and E. Wiedemann in the case of the unstratified discharge. Hittorf shows that the fall of potential is the same in the positive part for the same tube whatthe particles proceeding from the nega- ever the current. This means that the

current, and not to the square of the current as in a liquid. In the latter form the proposition had previously been proved by E. Wiedemann, who has shown that the total quantity of heat generated is proportional to the total quantity of electricity which has passed through the tube, whether in a few strong sparks or many weaker ones.

These experiments seem to point to the fact that once the original velocity of the particles at the regular pole has been reduced the velocity becomes independent of the strength of the current, that is to say, that in the positive part of the current greater intensity only means a greater number of particles taking place

in the discharge.

The paper also contains spectroscopic evidence as to the state of dissociation in a vacuum tube, especially in the negative

glow.

The question as to how the electricity passes from the electrode to the gas is not discussed, nor is it possible at present to decide, should the theory prove true, whether the polarity of the atoms the illustrations accompanying it.

energy dissipated is proportional to the in the molecule depends on the way in which these are combined, or whether that atom takes positive polarity which happens to be nearest the negative electrode as the molecule approaches it.

In conclusion some novel influence of the magnet on the negative glow is described, and it is shown that two different effects have to be clearly distinguished. The first is an effect of the magnet on the discharge when that discharge is established, and has been sufficiently well investigated. But the second effect depends on the question from what part of the negative electrode the discharge sets With respect to this question we out. meet with many contradictory and inaccurate statements. If at any place the magnet tends to throw the glow together the temperature will be raised, and owing to this fact the current will be strengthened, which again raises the temperature. It may thus happen that a slight cause can induce the current to pass almost exclusively from one part of the negative electrode. For a detailed description the reader is referred to the paper itself and

THE TIDAL WAVE AND THE "MASCARET"—IMPROVEMENT OF TIDAL RIVERS.*

BY E. SHERMAN GOULD, C. E.

Reviewed for Van Nostrand's Engineering Magazine.

science more interesting than that which astronomy. The quiet void of the heavrelates to the observation of the move- ens and the undeviating march of the ments of the ocean and the study of the stars, seem to furnish fit elements for the laws which govern them; and perhaps exercise of an exact science, but how few departments of applied science call hopeless, one would think, to search for for more genius, or demand higher qualifications than sea-coast and river engi-There is an awful grandeur belonging to the ocean which rivals in impressiveness the serene stillness of the star-lit heavens, while the triumph of man's intellect in mastering, even if only partially, the laws which the mighty restless mass of waters obeys, seems almost more wonderful

There is perhaps no branch of physical the conquest of the celestial spaces by fixed laws in that which is itself the type of instability!

> In the volume before us, Mons. Comoy has developed an admirable and comprehensive treatise upon the principal phenomena of wave-motion. Assigning to himself in the first instance the task of studying that curious phase of tidal action known as the mascaret, or bore, he found himself forced to trace back all the anterior phenomena connected with it, and has so been led to establish the whole theory of wave and tidal motion. This

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^{*} Etude pratique sur les Marées Fluviales, et notamment sur le Mascaret. Par M. Comoy. Paris, 1881. Octavo, pp. 389. Figures in the text and atlas of 10 plates.

labor which, in view of the author's main object was but a means to an end, becomes the most valuable feature of the work to the American engineer, because none of our rivers, we believe, present the peculiarity of the mascaret.

Waves may be broadly divided into two classes, namely, Waves of Transla-

tion, and Waves of Oscillation.

When a boat with bluff bows is forced along a canal, a certain quantity of water is heaped up under her fore-foot. Should the progress of the boat be suddenly arrested, there would be formed, after a brief period of tumultuous agitation, a wave which would detach itself and roll onward in the direction in which the boat had previously been moving. This wave would be a Wave of Translation. waves are formed when a mass of water is shoved forward horizontally by a sufficient force. They move along bodily, extending from side to side of the channel within which they were propagated, widening when the channel widens, the onward motion extending also from the surface to the bottom of the water.

The principal visible characteristic of a wave of translation is that it stands wholly in relief above the adjacent surface, like a hill rising from a level plain.

The velocity with which a wave of translation moves is proportionate to the depth of water in which it is propagated, and its height above the surface. It is represented by the formula

$$V = \sqrt{g(H+h)} \mp U$$

in which g=gravity and H and h respectively the depth of water in the channel and the height of the wave, and U the current, if any, in the channel, using the sign + or — according as it runs with or against the direction of the waves.

This velocity V is that of the undulation of the wave: not that of the forward horizontal movement of the molecules of which it is composed. This last velocity, represented by v is given by the proportion:

 $\frac{v}{V} = \frac{h}{H+h}$

The wave of translation does not reproduce itself: each wave requires a distinct force to generate it. For this reason French physicists give it the name of onde Solitaire.

Waves of oscillation are divided into two classes, ordinary and periodic. Of the latter the great example is the tidal wave.

The ordinary wave of oscillation is generated by any force which produces a temporary vertical depression or elevation in the surface of the water. Thus, a stone thrown into the water produces waves of oscillation. They always go in groups, and their principal visible characteristic is a series of alternate elevations and depressions above and below the general surface of the water. The wind, striking the surface of the water obliquely, produces by the action of its vertical component, waves of oscillation.

While the action of waves of translation exercised in the channels of moderate dimensions such as rivers and canals, in which their movements have been studied, extend undiminished from the surface of the water to the bottom, that of the wave of oscillation which has been investigated on a much vaster scale, extends to only a comparatively moderate depth, rapidly decreasing from the surface downward.

This statement must be made, however, under a certain reserve, and must be understood to apply, as regards oscillatory waves, to those of which the length and height are insignificant in comparison with the depth of water in which they are generated. When the dimensions of the waves are great in comparison with the depth of the water, the agitation which they occasion is felt to a greater or less extent through the entire depth.

Periodic waves of oscillation are generated by a series of periodic actions, each one producing a wave; the waves thus produced following each other in regular succession.

It is only the periodic wave of which the movements have been thoroughly investigated.

In deep water, the velocity with which a periodic wave of oscillation is propagated is given by the formula

$$V = \sqrt{\frac{g}{2\pi}} L$$

In which g=gravity, $\pi=3.1416$, and L= length of wave.

If the depth of water be less than the distance below the surface at which the agitation produced by the wave would be manifested if the water were deeper, we

should have, as an approximate formula,

$$V = \sqrt{g H}$$

in which H=depth of water.

The above are velocities of propagation, not of translation. It is generally understood that waves of oscillation have no regular horizontal progressive motion, but only an oscillatory movement, as the name implies.

As has been already stated, the tidal wave which twice in each lunar day traverses the ocean spaces of the globe, is the grand representative of the periodic

wave of oscillation.

Although this wave is due to the influence of the moon and of the sun, it does not follow the apparent path of these bodies, nor yet coincide with the times of their meridian transits. Thus, the wave coming from the South of Africa, after sweeping around the Cape of Good Hope, rolls to the north towards Europe and bears down upon France and England in a south-easterly direction. Part passes through the channel from west to east, and part goes around the North of Scotland into the North Sea, from north to south. This portion enters the channel from the North Sea, going west, where it meets that portion which, as we have seen, enters the channel from the west.

It would seem that the tidal wave owes its unvarying periodicity to the sun and moon, but once generated by these bodies it is abandoned, as to its future course, to purely terrestrial influences, namely the presence of continents and the greater or less depth of the sea.

The ocean tidal wave is of relatively low height, but immense length and velocity. In seas of great depth, say of 2 miles and over, like the Atlantic, it attains the prodigious length of 5,000 miles. Owing to its great length, we must conclude that it causes motion down to the very bottom of the seas which it traverses.

Owing to the same fact, we have the curious anomaly to encounter, that the wave, in passing over the deepest seas, falls under the classification of an oscillatory wave propagated in shallow water. Its velocity is therefore, as before

$$V = \sqrt{g H}$$

Direct observation confirms the correctness of the above formula.

Besides the above velocity of propagation, there are the ebb and flood currents. These currents are more perceptible in proportion as the water becomes shallower.

We may note as one of the remarkable phenomena of the tides, that the turn of the tide does not correspond with high and low water, the ebb commencing before the water has ceased rising, and vice versa.

It would be impossible within our limits to even glance at Mons. Comoy's masterly analysis of the various movements of the tidal currents and their causes. Suffice it to say, that he finds them to conform to the *law of least action*, in the exchanges of water necessitated by the undulations of the wave, and that they are exclusively undulatory, having no connection, at least in mid-ocean, with the slope of the surface of the water.

The formula for the mean velocity of the flood-tide is given by the proportion

$$\frac{v}{V} = \frac{h'}{H}$$

In which v=mean velocity of tide; V= velocity of propagation, h' half of the total height of wave, and H=depth of water. By substitution of V= \sqrt{g} \overline{H} as already given, we have

$$v = \frac{h'\sqrt{g}}{\sqrt{H}}$$

for the mean velocity of the flood current.

This formula has been verified by observations in the English channel, near

the Pas de Calais.

To calculate the distance traveled by a molecule of water on a flood-tide, Mons. Comoy gives the formula

$$l = \frac{\lambda v}{V - v} = \frac{\lambda h'}{H - h'}$$

in which l=the distance; v=mean velocity of flood current; V=velocity of propagation of wave; $\lambda = \frac{L}{2}$ half length of wave; h'=half height of wave, and H=depth of water. The length of the wave is given by the formula

$$L=T\sqrt{gH}$$

in which T=mean half lunar day in seconds=44,400 seconds.

Mons. Comoy gives some very interest-

ing numerical examples of these formulæ, checked when possible by direct observation, but our limits bar these out, as well as much other interesting matter.

Let us pass to the tides which enter the estuaries of tidal rivers. When the tidal wave of the ocean passes in front of the mouth of an estuary, a wave of derivation is detached, which passes up the river. The duration of the tide in the river is the same as that of the ocean tide which caused it, but this is the only point which the two have in common. tidal wave in the river is essentially a wave of translation, or rather a series of such waves, for Mons. Comoy says:-

"When the sea, lifted by its undulatory movement, begins to exceed in height the level of low water in the river, the water projected into the river produces a first wave which travels up the stream with a velocity proportional to the low-water After this first introduction of the water of the sea, and continually during the whole of the flood tide, the sea, always higher than the water in the river, projects into it new masses of water which give rise to new waves of translation. All of these waves are propagated, like the first, in virtue of the law of their regimen, while new waves are constantly forming at the mouth of the river. any given moment, therefore, of the flood tide, we find between the embouchure and the first of the flood, a continuous series of waves of translation occupying the entire length of the tide, and forming by their aggregation the forward slope of the tidal wave of the river, at that moment."

For the velocity of propagation of the crest of the tidal wave in the river, we have

$$V = \sqrt{g H} - U$$

the same as for the ocean wave less U, or the down-stream velocity of the river.

As the depth of water in the river diminishes, \sqrt{g} H diminishes also. When for any elementary wave it becomes=U, that wave ceases to exist.

The distance traveled by a molecule of the water of the flood-tide is given by the formula

$$l = T V \frac{v}{V - v}$$

of duration of flood; V=mean velocity of propagation of flood-tide during the time T; v = mean velocity of flood current over the distance l.

Observed velocities show that the ratio

 $\frac{v}{V-v}$ is rarely less than $\frac{1}{3}$, while in some rivers of shallow depth it becomes $\frac{1}{2}$.

This formula has been verified by observing the distance to which the salting of the river water by that of the sea extends in some of the French rivers.

In the chapters devoted to the mascaret, Mons. Comoy goes into great detail respecting the cause and theory of this phenomenon. We will not follow him through this interesting investigation, further than to state the conditions which he finds to exist whenever the mascaret

is produced. The principal condition necessary to the formation of the mascaret, is as follows: during any given period of the flood-tide, a certain quantity of tidal water enters the embouchure, represented by Svt, in which t = any given time, during which the tide at the embouchure rises through the distance C; v = mean velocity of flood-tide at the embouchure, during the time t; S = meancross-section of the embouchure of river during the time t. This quantity of water after entering the river occupies a volume represented by DLA; in which D=mean distance between the embouchure and the first of the flood; or the distance traveled up the river by the tidal wave, during the time t; L = mean width of river over the distance D; A=mean rise of the tide during the time t, over the distance D.

These two volumes are necessarily equal, for they represent the same quantity of water in two different positions, so we have

Svt = DLA.

If a mascaret is produced, it will always be found that in the above relation, A> C. C, it will be observed, forms part of

In other words, it is found, that when the mascaret is produced, the height to which the tide rises in the river during the time t, is greater than that of the rise of tide at the embouchure, during the same time. Moreover, it is found, that, in which l=distance; T=time in seconds leaving out exceptional cases, the mascarare formed inside of the mouth of the river.

In regard to the improvement of tidal rivers, Mons. Comoy confines himself to the consideration of the effects upon the regimen of rivers, by deepening their shallow places, without discussing the means by which such deepening may be effected. He makes the very true remark that the regimen of rivers differs so much in different cases, that we may say with justice that there are as many particular regimens as there are rivers. Some features, however, similar rivers possess, in common, and these are ably studied.

Two very broad classes may be made of tidal rivers; those of which the bar is formed within the mouth, and those of which the bar is formed outside of the mouth. (In this latter case only, is the tle more than, as it were, rapidly turn shallow portion termed bar in English.)

Mons. Comoy states, that in all rivers where the bar is formed outside, or to seaward of the embouchure, there is a marked narrowing of the mouth, the river being much wider for a certain distance above, than it is at the mouth, or embouchure itself. This narrow part is consequently deep, and the bar is formed (pergreat, being deposited outside the mouth. treats.

et only exists in rivers of which the shoals In rivers where the bar is formed inside the mouth (or where, as we should say, there is no bar) the embouchure is on the contrary wider than the rest of the river. It is in such rivers that the mascaret is most prone to exhibit itself.

> In order to obtain actual data regarding the regimen of tidal rivers, the Administration des Ponts et Chaussées, authorized observations to be made for Mons. Comoy, of several of the most important tidal rivers of France. These observations were made simultaneously during the spring-tide of Sept. 19th, 1876 and the neap-tide of the 26th of the same month and year. "Instantaneous curves" were thus obtained of great value, which are given in the atlas accompanying the work.

In the foregoing we have done but litover the leaves of an exceedingly exhaustive and practical treatise upon tides and tidal rivers. Many valuable chapters have been passed over without notice, and over none have we dwelt long. Enough however, it is hoped, has been said to give some slight idea of the character and scope of the volume, and to commend it to the careful study of those haps not exclusively) by the scourings of scientists and engineers who are interthe narrow portion, where the velocity is ested in the subjects upon which it

TELPHERAGE.*

From "Iron."

The following short summary of the ily computed. 3d, we re-convert the elecwho have not studied the subject. There are three steps in this transmission—1st, we convert mechanical power into electricity by means of a dynamo; in doing so we incur a loss of from 10 to 20 per loss, depending on the distance of transthe electromotive force employed, is eas-

problem of the transmission of power by tricity into mechanical power by means of means of electricity may interest those an inverted dynamo, which we term an electric motor. With motors in which large weights of iron and copper are employed. the loss in re-conversion need not exceed 20 per cent., but with light motors, weighing from 70 lb. to 100 lb., per cent.; 2d, this electricity, in flowing along horse-power, such as we must employ in a conductor, generates heat, representing the locomotives, I could not undertake a further loss, analogous to that resulting with certainty at this moment to effect from friction in mechanical gearing. This the reconversion without a waste of onehalf. The effect of all these sources of mission, the size of the conductor, and loss is, that at the stationary engine I must exert about 3 horse-power for every single horse-power which is employed usefully on the line. I look forward con-

^{*} Abstract of Prof. Fleeming Jenkin's paper before the Society of Arts.

fidently to the time when 2 horse-power at the engine will be sufficient to give 1 horse power to the motor. To put these conclusions in a more scientific form, I may assume the efficiency of my dynamo as 80 per cent., that of my small motor as 50 per cent.* The waste by heat expressed as horse-power is equal to $\frac{\text{C}^2\text{R}}{746}$ where C is the current in amperes, and R the resistance in ohms. The horse-power represented by the current is equal to $\frac{\text{EC}}{746}$ where E is the electromotive force

in volts, and C the current in amperes. It follows from the last expression that I may increase the horse-power in three ways, by increasing either E or C, or both. If I increase E, leaving C the same, I do not increase the loss during transmission along the line, no matter what horse-power the given line may transmit. A practical limit is set to the application of this law by the difficulty met with in dealing with electromotive forces above 2,000 volts. Marcel Deprez, taking advantage of this law—first pointed out by Sir William Thomsonhas transmitted seven or eight horsepower over seven or eight miles, through an ordinary telegraph wire, and he obtained a useful duty of 63 per cent., taking into account all the three sources of loss which I have enumerated. small motors I cannot yet promise a result so good as this, and I merely mention it to let you understand that, in speaking of 3 horse-power for one at the locomotive, I am leaving a very ample Quitting generalities, I will give some details as to the electrical and other conditions necessary, in two examples, for what may be considered as typical telpher lines.

First line.—Length, five miles. Length of circuit, out and in, ten miles. Twenty-five trains running at once, spaced one-fifth of a mile apart; speed, four miles per hour. Let each require 1 horse-power on the average; let the motor take on the average two amperes of electric current; let the electromotive force near the stationary engine be 840 volts; the electromotive force at the end of five

fifty amperes at the near end of the line. Fifty amperes and 840 volts represent 56.5 horse-power; of this, 6.5 horsepower will be wasted in heating the line; the remaining fifty horse-power will do work in the motors equivalent to 25 horse-power. In order to give this current of fifty amperes with 840 volts the stationary engine will require to exert $\frac{1.0}{8} \times 56.6$ horse-power, or roughly, 70 indicated horse-power, or somewhat less than three times the useful horse-power. Let us now examine the economical results to be obtained from such a line as Mr. Dowson, in an interesting comparison between the cost of horsepower obtained from coal and gas, reckoned the cost per horse-power for a 100 horse-power engine, at the rate of £3 6s. 9d. per annum, to include wages, coal, oil, and depreciation. Mr. Dowson would naturally be led to put the cost of steam power obtained from coal rather high than low. I will, however, adopt a very much higher figure, and assume that the power may cost as much as £6 10s. per horse-power per annum; this gives £455 as the cost of the 70 horse-power required for my telpher line. Let the twenty-five trains each convey a useful load of 15 cwt. In a day of eight hours the line will have conveyed a traffic which we may express as 600 ton-miles, i. e., it will be equivalent to 600 tons conveyed one mile, or 60 tons on each line conveyed from end to end daily. If we count 300 working days in the year, the sum of £455 gives £1 10s. 4d. per diem, and the 600th part of this is about 0.604 of a penny, as the cost of the power required to carry a ton one mile. In Great Britain we ought easily to be able to reduce this below a half-penny per ton per mile, which proves that the apparent great waste, even of two-thirds of the power in transmission, does not involve prohibitory expense. In calculating the whole cost of transport, we must further take into consideration the cost of the installation. Taking the spans at 70 feet, I estimate this cost as follows:

miles will be about 746 volts.*

total current entering the line will be

The

^{*} The last motor tested, weighing 117 lb., made by Mr. Reckenzaun, gave 1.72 horse-power with 54 per cent. efficiency.

^{*} It has been suggested that this fall of potential would be inconvenient for electric lighting, it would be too great; but in Telpherage it would simply cause a small decrease in the speed of the train at the far end, and as all trains would be equally affected, none would overtake the other, and no inconvenience whatever would arise.

Line £500 per mile	£2,500
Engine, boiler, and shed, at £20 per in-	
dicated horse-power	1,400
Dynamo and fittings	1,000
Twenty-five trains	
Contingeneies	
Contingencies	

Total cost.....

Allowing $12\frac{1}{2}$ per cent. for interest and depreciation, this represents an annual cost of £1,000. Allowing £100 as the salary of an electrician or young engineer, and adding £455, the cost of the power, £1,555 for a daily duty of 600 ton-miles. If we continue to assume the year as cost of conveying one ton one mile will be found equal to 2.07d. If goods are to be transmitted for long distances, the mile, by the agency of the suspended telpher line.

96 ton-miles. fresh outlay on the line itself.

problems involved, but time does not permit me to enter into the consideration of these to-night. It will be sufficient for electricians when I say that I se mey way to governing, blocking and breaking the trains, without ever interrupting the current used to work the motor, except between the line and rolling wheels. We already know that the interruption at this point, although accompanied by a spark, does no injury whatever. I have often been asked whether the frequent rethis gives a total annual expenditure of versals involved in the cross-over system do not tend either to injure the dynamo or the motor. I made special expericontaining 300 working days, the total ments on this very point lately with a compound wound Crompton dynamo and Mr. Reckenzaun's motor with thirty-six coils. I was unable at the commutator same calculation applies. We should of the motor to detect the smallest simply have stations ten miles apart, change in the motion due to the most working lines five miles long on each side rapid reversal. At the dynamo commuof them. This, then, is the practical out-tator I could just see when the reversal come of the general principles stated at occurred, but there was no change of a the beginning of this paper. We may character to cause the smallest alarm. At expect with great confidence that it will the same time I may state that, when pay investors to convey goods for any from any cause reversals may be thought distance at the rate of 2d. per ton per undesirable, we are in possession of apparatus which we call "step overs," which, without diminishing the simplicity of the Second Line.—Matters are somewhat permanent way, enable us to send a conmodified when the traffic is smaller, tinuous and unreversed current. These Making similar calculations for a line one and similar electrical questions, such as mile long instead of five, with only four the performance of Messrs. Ayrton & trains running at once, we might employ an electromotive force as low as 100 volts; Perry's excellent motors, might possibly have had greater interest for electricians the loss by heating would be insignificant; than some of the mechanical details diswe should require about 12 horse-power; cussed to-night; but I have felt that the the work done in eight hours would be main point to establish, in bringing this I estimate the cost of in- invention before the public, is that we stallation at £1,600, and the annual cost have in telpher lines a means of conveyof working £344, without the annual ing goods in an economical manner, by salary of an electrician. This corre- lines, locomotives, trucks, dynamos and sponds to 2.875d., or less than 3d. per motors, which have undergone their preton per mile. One very important feature liminary trials with success, and can be in respect to the cost of telpher lines is at once applied to the more searching the fact that the larger part of that cost test of performing work for the public. is due to plant, such as locomotives, If I have established this fact, I think trains and dynamos. This plant can be you will have no difficulty in believing increased in proportion to the work rethat the subsidiary electrical problems quired; thus there is a very moderate have been, or will be, readily solved. I increase of cost in the rate per ton per hope that at a future period these will be mile for a small traffic as compared with brought before you in detail on many oca large one, and, on the other hand, a casions by many men. In conclusion, I line laid down for a small traffic will ac- will enumerate some of the uses to which commodate a much larger traffic with no telpher lines may be put. They will convey goods, such as grain, coals and all There are numerous minor electrical kinds of minerals, gravel, sand, meat, fish,

will be so many sources of power, which establishment and maintenance. can be tapped at any point, for the execu-

salt, manure, fruit, vegetables; in fact, tion of work by the wayside. Circular all goods which can be divided con-saws, or agricultural implements, could veniently into parcels of two or three be driven by wires connected with the hundredweight. If it were necessary, I line, and this without stopping the traffic should feel no hesitation in designing on the line itself. In fine, while I do lines to carry weights of 5 or 6 cwt. in not believe that the suspended telpher each truck. The lines will carry even lines will ever compete successfully with larger weights, when these, like planks railways, where the traffic is sufficient to or poles, can be carried by suspension pay a dividend on a large capital, I do from several coupled trucks. The lines believe that telpher lines will find a admit of steep inclines; they also admit very extended use as feeders to railways of very sharp curves. Mere way leaves in old countries, and as the cheapest are required for their establishment, mode of transport in new countries. In since they do not interfere with the agricultural use of the ground. They argument mainly on the cost of different could be established instead of piers, modes of transport, which may, I believe, leading out to sea, where they would load be stated approximately as follows: Railand unload ships. With special designs, way, 1d. per ton per mile; cartage, 1s. they could even take goods from the hold per ton per mile; telpher lines 2d. per of a ship and deliver them into any floor ton per mile; and let it be remembered of a warehouse miles away. When esthat, in taking the cost of cartage at 1s. tablished in countries where no road per mile, the first cost and maintenance exists, the line could bring up its own of the road is left wholly out of account; materials, as a railway does. Moreover, whereas in my calculations for the telpher wherever these lines are established, they line allowance has been made both for

THE NILE DELTA.

NOTES OF A JOURNEY THROUGH THE N.E. FORTION OF THE DELTA OF THE NILE IN APRIL, '84. By WILLIAM ANDERSON, M. Inst. C. E.

From Papers of the Institution of Civil Engineers.

Having been commissioned to ascer-Mansoura, a large town on the Damietta perity depends. Nile, and Lake Burlos, a lagoon conorigin.

The welfare of the agricultural industain why extensive estates belonging to try, the only source of wealth in Egypt, an English Company were wholly unpro- depends mainly on the efficiency of the ductive, and indeed incapable of earning irrigation, the drainage, and the means the Government land-tax, it is thought of communication. It soon became apthat the observations then made may be parent, that the estates visited, and many useful to all interested in the true wel-thousands of acres of land around them, fare of Egypt. The district visited was were suffering from startling defects in that portion of the Delta lying between all the three conditions on which pros-

First, as regards Irrigation. The pornected with the Mediterranean, and thus tion of the Delta inspected, and, indeed, quite outside the usual track of visitors. the whole Delta, is intersected by innu-The inquiries and investigations were of merable canals, some used for drainage a definite and practical character, and and some for irrigation. These have have produced a profound impression as been dug at various times, for the most to the state of the administration, and as part without reference to any general to the manner in which the resources of plan. They are practically devoid of the country are destroyed at their very proper locks or sluices for regulating the flow of the water, the method adopted

arterial canals. This state of things is peculiarly distressing just at this time, when the number of bullocks has been greatly reduced by a formidable epidemic, so much so, that it will be impossible, this season, to cultivate even so much of the land as is capable of being worked.

In the next place, the drainage-canals have been much neglected, especially at their lower ends or outfalls. They all require widening and deepening, so as to carry the drainage waters into the sandy tion intersect the country in all direcwastes skirting the Mediterranean. The tions, and yet it costs 26s. a ton to bring fall of the country is rapid, so that there the produce from the estates visited, a Department to attend to this important during the dry season, because rain part of its duties, injures not only the makes the towing and bridle-paths imlands depending upon the public canals, practicable. This state of things could but also estates such as the ones visited, be remedied at a most insignificant cost. which, lying on the edges of the waste. The impediments to cheap communica-

being to throw banks of earth across the for it is in vain that these are kept in canals, leaving gaps of sufficient width proper order, when the water standing to control the water, these gaps being on the adjoining lands percolates through regulated by stakes, planks, or lumps of the soil, and rises in the better drained mud wrapped in rice straw. Owing to portions, bringing up with it the deletethe caprice, corruption or laziness of the rious salts with which the whole subsoil officials, the water in the irrigation of the Delta is more or less impregnated, canals is often too low to command the so much so, that this salt may be seen land, even when the Nile is high enough lying like snow over vast areas of land. for the purpose, and at other times the It is absolutely essential to the fertility water is allowed to pass so freely as to of the land that the drainage-canals overflow the banks and submerge large should be constantly kept clear, and that tracts of country. In summer time, be- there should be an unfailing supply of tween the months of May and of August, irrigation-water all the year round, beduring low Nile, many of the canals, for cause it is only by keeping a regular want of proper cleaning and maintaining wash of water from the surface downat the required depth, become quite dry, wards that the deleterious salts can be and thousands of acres of summer crops, prevented from rising; but when this is such as cotton and rice, perish for want done, the fertility of the soil is marvelof water. In the district visited, two- ous, and the richness of the crops is, thirds of the crop was, last summer, com- for the most part, assured. Adjoining pletely lost from this cause. But even one of the estates was a property of when the canals are properly cleaned out, 1,400 acres which had been abandoned the water is still below the land-level, by its owner for no other reason than and every drop required for irrigation that the Government drainage-canal was has to be raised by imperfect sakiehs, and choked with mud and aquatic plants. The small steam-pumps. These may be seen Government had seized the land for dotting the landscape in all directions, taxes; it had twice put up the property and represent an incredible amount of for sale without finding a purchaser, and, human and animal labor diverted from of course, had lost the revenue from the the more legitimate work of tilling the lands. A single year's taxes would have soil. The cost of this wasteful mode of sufficed to clean out the canal. This is a raising water is at least ten times greater particular case, respecting which definite than that for which the same work could information was obtained, but many be done by large Government pumping thousands of acres of other lands were stations, or by a better management of in a similar predicament, as, for example, of the 100,000 acres belonging to the village of Massara, only 12,000 acres are capable of cultivation, on account of the neglect of the drainage and want of irrigation-water.

Lastly, mismanagement has practically destroyed the means of communication. The canals, if properly maintained, would be wide and deep enough to carry cargo-boats as large as those in use in England. These arteries of communicais no difficulty in securing very efficient distance of only 33 miles, to the Damietta The neglect of the Works Nile, and even that can only be achieved

had their own private drainage-canals; tion in a country so highly favored with

what may be termed natural roads are means of communication are so defectthe following:

When the canals are cleaned, the mud is thrown up on to the towing-path, and allowed to harden in the sun, without the least attempt to level it or remove it altogether from the path. The consequence is, that the animals using the bank of the canal tread a bridle-path on a slope. all times is difficult foothold, and in wet weather, when the mud gets slippery, becomes dangerous, and even impracticable. Trees are allowed to grow between the towing-paths and the canals, so that in many places towing is impossible, and from the opposite bank trees overhang, inexplicable, because it would entail very so that the towing masts cannot pass. Naturally all these obstructions should to keep the canals in proper order, while be removed. The banks thrown across the flow of water render trans-shipment necessary, and in this way, in the 33 animal labor now lost in raising water in miles of canal specially visited, there a wasteful manner, and in overcoming were no less than four dams of weirs, the difficulties of transport. necessitating four trans-shipments. The inches. It would be very easy and inexlock gates and sluices, which would allow dues, which would amply cover all ex- rate, it would be an infinitely smaller inagain, thus intersecting the roads with innumerable pitfalls, which render travelling in the daytime fatiguing, and at night impossible. Surely a very moderate amount of supervision would put an right its finances. end to this nuisance.

Egypt depends for its prosperity on its agricultural produce; but the competition of the whole world, the immensely improved ways of communical the root of the matter. Measures should tion in America, in India, in Russia, have be adopted to place the cultivatable porhad the effect of reducing the price of tion of Egypt in a condition to produce all the products which Egypt can send the wealth latent in its lands, in its river, into the market, more especially that of and in its laborious peasantry, and furcereals, and the price is never likely to ther to provide cheap and expeditious rise permanently again. How is it post ways of communications, which can sible that those portions of Egypt which alone enable the produce of the lands to lie at a distance from Alexandria can be converted into the gold which the hope to export their produce when the financiers thirst for. It would be a

ive? The inevitable result will be that the country must relapse into a state where just enough is raised to feed a miserable population, and no taxes will be paid, because, there being no sale of produce, there can be no money.

Whatever neglect there may be in the This at maintenance of the canal-system, there is no slackness in collecting the landtax, and defalcation is quickly followed by seizure and forced sales, entailing ruin, misery and discontent among the

agricultural population.

The conduct of the Administration is little more than the present expenditure it would improve the revenue by making the canals for the purpose of regulating a greater breadth of land cultivatable, and would restore to the land the human and

The people do not object to forced difference of level between the two sides labor on their own canals. They have of the dams is never more than a few sense enough to know that by no other means can the life-giving streams be pensive, in the tenacious soil of the maintained, and it is possible so to dis-Delta, to construct wooden dams, with tribute the work, and so to select the season for doing it, that the task would of the barges being locked through, and not press seriously on the people. At any penses, would be cheerfully paid, as they fliction than that which now exists as the are in other countries. Again, no con- consequence of neglect and mismanagetrol is exercised over the cutting of the ment, by which the poor struggling peascanal-banks for irrigation or drainage- ants see the fruits of their labor disappear branches. The people cut through the year by year, for want of irrigation and banks, and neglect to make them good of drainage, or, if the harvest be haply secured, rendered valueless by the cost of carriage.

Many distinguished men have, from time to time, been sent to Egypt to set Many ingenious schemes have been proposed, but it is doubtful if an who have attempted the regeneration of the finances of the country have turned their attention to

worthy task for England to step in and remove the terrible drawbacks under which the fellaheen suffer. In her Indian engineers and their subordinates she has an admirable and experienced staff of administrators. The same men, the same system, and the same honesty of purpose introduced into Egypt would make a garden of a country which is now almost a wilderness.

A step in the right direction has already been made in the appointment of Colonel Scott Moncrieff, R. E, to the post of Under Secretary of State for Public Works. He has earned a high reputation in India, and will assuredly, if properly supported, do much towards the regeneration of the country entrusted to his care.

Unfortunately, long neglect and mismanagement have rendered large expenditure necessary, while that very neglect and mismanagement have crippled the revenue.

Colonel Moncrieff, has already been ordered to retrench in every possible way, even when it is certain that expenditure such as he contemplates will yield enormous return. He is perfectly alive to the importance of the reforms alluded to. In two "Notes" addressed to the Financial Advisers of the Government, one dated February 13th, 1884, on the communications throughout Egypt, and the other, dated March 4th, on the Public Works which he deems essential to the good administration of the country, he points out in terse and vigorous language the real barriers interposed to prosperity, in the absurd and oppressive taxes on navigation, the impediments offered to it by bridges over the main channels, the defects of drainage and irrigation, and the total absence of roads.

It is satisfactory to be able to state that recently in Egypt one great concession was announced, namely, the river and canals were set free for steam-navigation, a privilege till then reserved to the Government. It cannot be doubted but that this has been one of the results of the improved administration of the Public Works Department, and it is to be hoped that many other reforms will soon follow.

The uncertainty which surrounds the intentions of the British Government is stopping all public and private enter-

prise, and the poor farming population, that is to say, the bulk of the people of Egypt, is sinking deeper and deeper into a hopeless condition of poverty and debt. This is not a mere statement of opinion; on the contrary, the existing political situation had to be taken into considera-The canals and drains on the estates visited had long been neglected. An expenditure of £1,500 in cleaning out was absolutely necessary, if advantage was to be derived from the expected improved irrigation and drainage service; and could the company have felt sure of the intentions of the British Government to continue steadily in the course they have entered upon, the work would have been commenced at once. The probabilities are, indeed, in favor of a prolonged occupation, because a great number of British officials have entered the Public Works Department, replacing some able and experienced men, such as Rousseau Pacha and his chief engineer, and it is hardly credible that the British Government would make such appointments if their sway was to be only of a temporary nature. But still the Government assurance is wanting, and it is impossible to advise expenditure of capital which would be fruitless in the event of the withdrawal of the British, for in that case the Government of Egypt would relapse into its original state of inefficiency.

In 1883 the Ministry of Public Works in Shereef Pacha's Government published a most able paper entitled "Exposé du Ministère des Travaux Publics sur les Irrigations d'Egypte, et examen d'une proposition y relative."* It is signed by Ali Pacha Moubarick, then Minister of Public Works, and by Rousseau Pacha, their Director-General. These gentlemen are both men of long experience in the department over which they presided, and Rousseau Pacha, especially, is an engineer of great and varied informa-The "Exposé" treats first of the general systems of irrigation and drainage in vogue in Upper and Lower Egypt, discusses the capacity of the Nile at low water, and demonstrates that its volume is barely sufficient for the wants of the existing summer cultivation, and those of navigation. The long-standing question

^{*} An abstract of this will appear in the Minutes of Proceedings, vol. lxxvii.

and the conclusion is reached, that even ish the most oppressive kind of forced supposing by an expenditure of very large labor, would avoid all risk of infiltration, sums of money the Barrage could be re- would assure abundant water at all paired, or. as they point out, more prop- times at a height to command the land erly rebuilt, and the banks of the arterial irrespective of the level of the Nile, and canals raised to a proper height, to con- last, but not least, would save the Govvey the waters pent up behind it, Government might well recoil before the great measure, from the very heavy anenormous risk of so powerfully altering the regimen of a river such as the Nile, and incurring the consequences of injury to a wide extent of productive land brought on by the infiltrations which would be sure to supervene. In addition, they draw attention to the enormous cost of keeping the arterial canals clear, and the absolute necessity of employing for that purpose forced labor in its most odious form, that is, at a distance from the homes of the laborers, and employed on works in which they have no direct involved in cleaning the Rayah of Khatinterest. The height to which the banks of the arterial canals have risen from centuries of cleaning, renders the labor more and more severe each successive year, and more and more land is being covered by the mud excavated, and by that means rendered valueless. Rayah of Khatatbeh, in the western margin of the delta, for example, which used to bring the waters of the main Nile from above the Barrage to the Khatatbeh canal, which irrigates the Province of Behera, though only 26 miles long, required annually the labor of 20,000 men of feeding this army used to amount to the expense of many salutary reforms, £12,000, and if to this the labor lost to the farms and valued at only 6d. per head per day be added, there was a further loss to the country of £25,000, making £37,000 per annum for 26 miles of one canal!

In addition, the mud deposited in the arterial canals is the fertilizing essence of the Nile water, and should be deposited on the lands irrigated, and not in the canals. Too much importance cannot be attached to this point. The canals should be as short as possible, and then their currents can be so regulated that the least possible deposit shall take place.

On all these grounds the Exposé strongly advocates the use of powerful steam-pumps, under Government control, in preference to attempting to patch up the Barrage, or make use of long

of the Barrage is carefully considered, arterial canals. The system would abolernment for some years to come, in a nual outlay in cleaning canals used for the summer water, which now have to be maintained at a great depth, but which, if pumping be resorted to, may be allowed to silt up permanently to a very considerable extent. The Government of Egypt, before the rebellion, had already acted on the principles laid down in the Exposé, and had established a powerful pumping station at Khatatbeh. and increased the existing one at Atfeh, so as to save the expense and oppression The Government of Shereef atbeh. Pacha took up the good work, and all but made a contract with an English company to utilize its powerful pumps at Cherbine, which would have supplied the district visited, and invited tenders The for the erection and working of another similar station for the Mansourah district. Unfortunately the troubles in the Soudan broke out, Nubar Pacha replaced Shereef, and the arrangements made by the Government of the latter were in a great measure set aside. Colonel Scott Moncrieff (who was appointed about this for fifty days to clean it. The bare cost time) was forced to reduce his budget at and unfortunately with respect to the water supply of the district, which forms the subject of these remarks. At first Colonel Scott Moncrieff seemed favorable to the views advocated in the "Exposé" of the late ministry; but after the Soudan troubles, driven, perhaps, by pecuniary necessity, he unfortunately determined to make an attempt to raise the waters of the Nile by means of the Barrage, and that work is now being strengthened in a manner which he expects will enable it to perform the office for which it was de-Most experienced engineers, signed. native and foreign, believe that the attempt will end in failure. Mr. B. Baker's graphic description of the work* is of a very discouraging kind, especially as it

^{*} Minutes of Proceedings Inst. C. E., 1879-80,

ing examined with the view to converting traversed many miles of the canal-system it into a railway bridge, a diver was actu- both in Upper and Lower Egypt, and ally able to make his way right under everywhere the same neglect of the vital and across a portion of it! Colonel interests of agriculture exist. Nothing Moncrieff is very frank about his attempt, but a strong Government, served by capand is quite prepared for a failure; but a able and honest officers, will be able to invaluable purpose in regulating the civilized countries with which it has to amount of water passing down the Dam- compete. ietta Nile. tendency of the river to follow the for the construction of regulating resershorter, or Rosetta branch, hence, if any voirs on the Upper Nile are, as Rousseau serious failure of the Barrage were to oc- Pacha points out, works requiring long cur, the lands depending on the Damietta years and large sums of money. But Nile would suffer severely. Colonel Scott the immediate necessities of the cultivat-Moncrieff and his assistant have been but able lands can be satisfied with but moda short time in the country; they have erate outlay, and the returns will be not yet seen the Nile through all its immediate and abundant if the expendiphases. It would surely have been more ture is controlled by capable and honest prudent to postpone the dangerous exadministrators; but the work must be periment of dealing with the Barrage to done at once if the revenues of Egypt

a small portion of the country was that "the country cannot wait.

is known that when the Barrage was be- visited, yet at other times the author has failure may prove very disastrous indeed, achieve the reforms which will place the because, as Rosseau Pacha points out in irrigation, drainage and communications the Exposé, the Barrage now serves an of Egypt on a par with those of the other The grand schemes which Mr. Baker mentions the have from time to time been broached are to be maintained. The Ministry of Although on the present occasion but Public Works has declared emphatically

TEMPERATURE OF THE SUN.

BY F. GILMAN.

Written for Van Nostrand's Engineering Magazine.

made many statements which are undoubtedly erroneous, as we will proceed

He says: "The law that the intensity of heat diminishes as the square of the distance from the radiant increases, is applicable only to the case where the radiant body is considered as a mere point, and even in those cases the law does not give the temperature of the incandescent body. It is evident that Prof. Wood refers to a mathematical point, which has position but not magnitude, and assumes that a material body can occupy such a point, and, to cap the climax, tells us that body. No, to be sure it does not; but it the temperature of this point, or body, gives the temperature of the medium in must be infinite! As well might he say the vicinity of the body, and the temper-

In the last July number of this Maga-that the law that the intensity of gravitazine there appeared an article written by Prof. DeVolson Wood, in which he critithe distance is applicable only to a point, cised Capt. J. Ericsson's method of de- or (to speak more rationally) to a material termining the sun's temperature; and point, or particle of a body. But it has been proved that the same law of gravitation prevails in a spherical homogeneous mass of any dimensions, when the distance is measured from the center; and it is also applicable in the case of heat radiating from a spherical body, such as the sun; for gravitation, light, and radiant heat, conform to the same law. Prof. Tait, in his Treatise on Heat, declares that this law is necessarily true of any form of energy which spreads rectilinearly in all directions.

Prof. Wood says that the law does not give the temperature of the incandescent ature of the body cannot be lower than this, but must be higher, unless the emis-

sive power is equal to unity.

Capt. Ericsson has proved that the temperature of the medium in the vicinity of the sun is at least 1303640° Fahr. The temperature of the sun itself must then be fully equal to this, and is probably much higher. Prof. Wood says: "Experiment shows that the quantity of heat emanated from an incandescent body increases more rapidly than the temperature." This statement is incorrect. The quantity of heat lost by an incandescent body, in a given time, does not depend simply on its temperature, but rather on the difference between its temperature and that of the surrounding medium.

Prof. Wood gives the law deduced by Petit and Dulong in the following equa-

tion: $2 = 1.146 \, fa^{t}$.

We suppose there were some typographical errors in the explanation of symbols that follows, and therefore we will give what appears to have been the writer's meaning, in order, if possible, to get a little sense out of the formula. the quantity of heat per square centimeter emitted per minute, f the emissive power of the surface, its superior limit being unity; a=1.0077 while t is the temperature in degrees Centigrade of the hot body. It will be noticed that nothing is said about the temperature of the medium in which the body is placed, but let us suppose that it is constantly kept at o° C., as this supposition is the best that can be made consistent with the formula. Even in this case, however, it is seen to be incorrect; for making t=0 we have

$$2 = 1.146 f$$
.

That is, according this formula, when the body has cooled down to the temperature of the medium it is still losing heat, which is impossible; therefore the formula is false, or at least incomplete. The following formula given by Piclet in his *Traite de la Chaleur*, p. 373, vol. I., contains the proper expression of Dulong and Petit's law:

$$\mathbf{R} = (124.72) \,\mathbf{K} a^{\theta} (a^t - 1)$$

R represents the quantity of heat emitted by radiation per square meter per hour, K a number which depends on the nature of the surface, a the constant 1.0077, θ the temperature of the medium, t the extension that of the would not be far from that of the absolute zero, 460° below zero, Fahr.; and therefore the earth must at present receive from the sun an increment of nearly the temperature of the medium, t the extension t therefore the earth must at present receive from the sun an increment of nearly the temperature of the medium, t the extension t the extension t the sun an increment of nearly the temperature of the medium, t the extension t therefore t the extension t the exten

cess of the temperature of the hot body above that of the medium.

Prof. Wood, who expects such great things from this law of Dulong (which he has incorrectly given), seems to think that it holds true for any excess of temperature, however great; and would even, with Pouillet, apply it to determine the sun's temperature. In reply to this we quote from two authorities to show that Dulong's formula is only empirical, and that it ceases to be true when the excess of temperature is over 200° C.

"On voit donc d'abord que la formule de Dulong est empirique, puisqu'elle englobe dans une expression commune des elements qui sont differents, et ensuite, qu'elle doit cesser d'être exacte a des temperatures elevees."

Jamin's Physique, Vol. ii p. 314.

De la Provostaye and Desains have verified the consequences of this formula from o° C., to 200° C., but they state that above the latter temperature it is no longer applicable.

Tuit's Heat, p 279.

Hence appears the absurdity of applying such a formula as this to determine the amount of heat radiated (or conversely when the amount radiated is known to find the temperature) from a body like the sun, in which the excess of temperature is so enormous.

The principle which Capt. Ericsson applies, however, to determine the sun's temperature is perfectly general, and holds for any excess of temperature. It is susceptible of mathematical demonstration; and Capt. Ericsson has given in his sun motor an experimental demonstration

of it, which is unanswerable.

It seems as if some idea might be obtained in regard to the sun's temperature, by calculating what the temperatures at the earth would be, supposing it to advance by successive stages toward the sun. In order to know how much heat is communicated at present, we must conceive what would be the result if the sun were removed from the universe; or if its heat were entirely extinguished. In that case it is probable that the temperature here would not be far from that of the absolute zero, 460° below zero, Fahr.; and therefore the earth must at present receive from the sun an increment of nearly 400° Fahr. But we will take a much

only 100°, and then proceed to calculate earth's surface, were it advanced half-way to the sun's center, or at a distance of 46,000,000 miles. According to the prin- reach the sun. ciple above stated, the earth would then that it does at present; and assuming would be $4\times100^{\circ}=400^{\circ}$ reckoned from 400° Fahr.

smaller estimate, and suppose that it is the absolute zero, or 60° below zero, Fahr., I have assumed an initial temperature far what would be the temperature at the below that known to exist, in order to show to what a high temperature even that hypothesis will lead us, when we

Next, let the earth advance until it is receive four times the quantity of heat 23,000,000 miles from the sun's center. The temperature will be $4 \times 400^{\circ} = 1,600^{\circ}$. (which we may safely do in a question of | Continuing this process we shall find that this kind) that equal increments of heat when the earth is 718,750 miles from the correspond to equal increments of tem-sun's center, or 275,750 miles from its perature, the temperature at the earth surface, the temperature will be 1,798,-

THE STUDY OF IRON AND STEEL.

BY J. C. BAYLES, NEW YORK CITY.

Transactions of the American Institute of Mining Engineers.

agreeable duty of delivering an address progress. from the chair. The prominence which direction to my thought.

of accepted truth and verified experience, ligently and systematically studied. the work of original investigators is pro-

Gentlemen of the American Institute where else, build thereon a pier, and proof Mining Engineers; Ladies and Gen-tlemen: The propriety of imitating in these meet and are securely united, we everything, so far as I am able, the worthy have spanned one of the spaces between example of the distinguished gentlemen facts learned by observation and experiwho have dignified the honorable office of ence, and can safely pass over to a point President of the American Institute of from which new speculations and verifi-Mining Engineers, imposes upon me the cations may serve as a basis for further

We are impressed with the appropriatehas been accorded in the programme of ness of this figure when we examine the this meeting to the discussion of subjects steps by which we have gained what little connected with the study of metals, es-knowledge we already possess of the compecially iron and steel, has naturally given position and properties of iron and steel. That we know as much as we do concern-It seems to be characteristic of invening them is surprising, when we reflect tion and investigation that they conform that among our membership are many to no law of regular and uniform develop- whose lives almost include the period in ment. From the measurably firm ground which these materials have been intel-

The progress of chemical science apjected into the void of the unknown; and plicable to iron and steel analysis, naturso rapid and important are the accretions ally invites attention first. Before quanof fact around such slender spars of well-titative analysis was attempted, certain directed speculation, that it seems for a of the crude reactions of qualitative antime as if we might go on extending and alysis were recognized. Paracelsus, the building them up until the void was fully marvelous charlatan who lived from 1493 and safely bridged. But such a line of in- to 1541, knew of some of these; and Boyle, vestigation is like a cantilever with a pier an earnest worker in this field, records at one end and nothing at the other. The several in his "Essay on the Usefulness limitations, not only of knowledge but of speculation, become evident as we load 1671. Marggraf, who lived from 1709 to hypotheses upon the unsupported end of 1783, is the first chemist who is credited our structure; and to make our work of with analyses of minerals. Thomson, in his value, we must find a solid basis some- history of chemistry (London, 1831), says

of Marggraf's work: "His attempts were chemists, in order to draw important convery interesting record of his experimentdegree to advance the knowledge of the difference between iron and steel. He employed his pupils to collect specimens of iron from the different Swedish forges, and all of these specimens, to the number of eighty-nine, he subjected to a chemical examination by dissolving them in dilute sulphuric acid. He measured the volume of hydrogen gas which he obtained by dissolving a grain weight of each, and noted also the quantity and nature of the undissolved residue. The general result of the whole investigation was that pure malleable iron yielded most hydrogen gas, steel less, and cast iron least of all. The amount of Bergman's knowledge and the value of his methods may be judged from a table of percentages which he has left us, giving the composition of cast iron, steel and wrought iron. This table shows the following results:

Cast iron.	Steel. Wi	ought iron.
Inflammable air 40.	48.	50.
Plumbago 2.20	0.50	0.12
Manganese15.25	15.25	15.25
Siliceous earth 2.25	0.60	0.175
Iron	83.65	84.45

In manganese determinations Bergman evidently took care to avoid the discrepancies which are said to characterize the roth (1743 to 1817), soon after described work of modern chemists, for we find this metal as a phosphuret of iron, and that his manganese percentage is in each case 15.25 per cent. This celebrated chemist confirmed, to his own satisfaction, the conclusions of Réaumur (1683 to conducted a line of experiments in the 1757), who considered steel an interme-same direction about the time of Bergdiate grade of metal between crude and man's work, and he made his conclusions malleable iron. His experiments showed known to chemists in time to dispute that malleable iron left the smallest with Bergman a claim to priority of disquantity of insoluble residue, steel a covery. As may be supposed, Bergman's greater quantity, and cast iron the processes were rude and very imperfect. greatest of all, and from this he drew It was Klaproth who first systematized his conclusions with respect to the differ-chemical analysis, and brought the art to ence between iron, steel and cast iron. such a state that the processes could be "Nothing more was necessary," says Thomson, "than to apply the anti-phloresults in each case. Klaproth analyzed gistic theory to these experiments, as was about 200 specimens of minerals and metdone some time after by the French als, and most of his conclusions were so

rude, but their importance was soon per-ceived by other chemists, particularly by bodies. Iron is a simple body, steel is a Bergman (1735 to 1784) and Scheele compound of iron and carbon, and cast (1742 to 1786), whose industry and ad- iron of iron and a still greater proportion dress brought the art to considerable per- of carbon. The defective part of the exfection." Bergman, whose De Analysi periments of Bergman, as recorded in Ferri was published in 1770, has left a this important paper, is his method of determining the manganese in iron. In al work, which contributed in a material some specimens he makes manganese to amount to considerably more than one-third part of the whole. Now, we know," continues Thomson, "that a mixture of two parts of iron and one of manganese is brittle and useless. We are therefore sure that no malleable iron whatever can contain any such proportion of mangan-The fact is, that Bergman's method of separating iron ores was defective. What he considered manganese was chiefly, and might be in many cases altogether, oxide of iron. Many years elapsed before a good process for separating iron from manganese was discovered." To this I may add that many more years elapsed before steel containing 30 per cent. of manganese, of which some description will be given in one of the papers to be read at this meeting, became a commercial product.

> Among other investigations by Bergman were a series of experiments made by him with a view to ascertaining the cause of brittleness in cold-short iron. He extracted from such iron a white powder, by dissolving it in sulphuric acid. This white powder he succeeded in reducing to a white and brittle metal, by fusing it with a flux and charcoal. Klap-Scheele, with his usual sagacity, hit on a method of analyzing it, and thus demonstrating its nature. Meyer seems to have

nearly correct that his successors have, in that a piece of hardened steel dissolved most cases, confirmed the results he ob-When he began his researches, chemists were not acquainted with the true composition of a single mineral substance. The service which Klaproth performed for mineralogy in Germany was performed equally well in France by Vauquelin (1763 to 1829). To this chemist we are indebted for a description of the element chromium. All of the early analyses of ores, iron and steel are credited to one or the other of these two Vauquelin announced that in steel the carbon percentage averaged Phosphorus, he tells us, had long been th part. By inclosing diamonds in regarded as the prime cause of this qualprocess is employed at the present time, but judging from the disproportion frequently noted in experimental steel manufacture, between the cost and value of in use. Berzelius, in the first quarter of never yet seen carbon which exists in the present century, and Ebelmen, about crude iron, distinguished from that abten years later, made important contribuof his iron analyses shows iron 90.80, silicium 0.50, magnesium 0.20, manganese, 4.57, carbon, 3.90. The pupils of Berzilius were, to a great extent, instructors of the chemists of to-day.

Karsten, in 1820, recognized the influence of carbon on iron, and stated his belief that iron and steel constitute a continuous series, there being no distinct lines of separation between them. his judgment it was simply a question of carbon percentage where, in the series, a piece of iron or steel belonged. In his "Metallurgy," published in 1830, he notes the fact that pig iron contains carbon, silicon, sulphur, phosphorus, manganese, calcium, magnesium and chromi-It is probable, however, that all these elements had been previously recognized and described. As early as 1815 certain number of grains of wrought iron there was more or less speculation with charcoal in varying proportions and whether hardness and softness in steel note the increase of weight as showing were due to physical or chemical causes. the amount of carbon taken up. Karsten, ing been, in 1822, the first to point out racy of his methods, and proceeded to

completely in hydrochloric acid, while soft steel always yielded a certain amount of carbonaceous residue when subjected to the action of that solvent. Mushet, in Iron and Steel (1840), gives a very good idea of what was known of metallurgical chemistry at that time. He mentions certain ores which contain "phosphat" of iron, which was generally believed to account for the fact that the iron made from them was cold-short. Mushet, however, was by no means certain of the cause of cold-shortness. cavities of soft iron and igniting them, ity in iron, but by the practical observer they disappeared, and the inner surface this theory could not be considered tenof the cavity was found to be converted able, for it had always been noticed that I am not aware that this the most perfect qualities of iron, notably some of the Swedish makes, gave out in working "a very strong phosphoric smell." Regarding the condition in which carbon exists in iron, Mushet says, "In the works the product, one might suppose it is still of those who have treated on iron, I have sorbed by malleable iron in the process of tions to the knowledge of reagents and converting it into steel. I could," he methods. Berzelius was the successor continues, "adduce many facts which to of Bergman and Scheele. All previous me appear conclusive, to prove that caranalyses were revised by him, and mod-bon exists in crude iron in a concrete ern chemistry begins with his era. One state separable by mechanical division, and that it is united to steel in a gaseous state by the combustion of its base, inseparable in any form by the most minute mechanical reduction." It is surprising to note the earnestness and gravity with which in 1840, these statements were made. It shows the newness of the knowledge which now-a-days serves as the startingpoint for discussion on such topics.

Mushet treats very fully of the effect of different substances on the quality of iron. He made a number of experiments by fusing iron with different fluxes in crucibles, and noting the quality of metal produced. One section of his book is devoted to the different proportions of carbon which constitute iron and steel; and he gives the results of fourteen experiments. His method was to fuse a Faraday is credited by Percy with hav- however, promptly challenged the accu-

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entirely wrong—much as chemists of the care to pay more than \$10 a week." present day are prone to do upon occasion.

It is unnecessary to follow from this point the progress of metallurgical chemistry towards a scientific basis. Its general employment as a means of assisting makers to control the character of their product concerns us more; and this is almost within the memory of even the youngest of our membership. Most of us can recollect when the dependence of the iron-master and the engineer who cared to know the chemical composition of a piece of iron or steel, was upon the When the general analytical chemist. influence of our technical schools began to be felt, and young men well equipped for the work began to displace, in the management of furnaces and mills, those who had gained their knowledge in the school of experience, where the instruction is not always thorough in proportion to the cost of tuition, the laboratory began to be recognized as an essential part of an iron or steel-making plant, and in nearly every establishment with any pretensions to completeness, the chemist has become an important member of the staff. But it is not more than fourteen years ago that this was the exception rather than the rule. Among my letters I have one bearing date of 1872, written by the general manager of an important iron-works. He says: "The president of our company thinks we ought to follow the fashion and have a To my mind it is a waste of chemist. When I want an analysis I can have it made—and that is very seldom; for the furnace-manager who needs a chemist to tell him the quality of ore or limestone, or whether his pig iron is soft or hard, had better resign and go to farm-However, if the president says chemist, chemist it is. My object in writing is to know if you can recommend a young man competent to fit up a laboratory and take charge of it. We have very little society here, and it is desirable My that he should be a gentleman. wife plays the piano, and I do a little on the flute, and if we can get a chemist who

show that Mushet's tables giving the car- could employ him. I do not know what bon percentages in iron and steel were a chemist would expect, but I should not

When the demand for analytical work in connection with the iron and steel industry began to be felt, it brought into the service of the iron-master a great many clever and ingenious chemists at home and abroad, and a varied and valuable literature of metallurgical chemistry was soon created. The need of accurate analyses was so evident that their importance was, perhaps, somewhat exaggerated and for a time it seemed as if we might safely look to the chemist to answer every question which could be raised by the iron-master or the engineer. Our confidence in tabulated percentages of the component parts of a piece of iron or steel resulted largely from the fact that we knew so little what knowledge was needed for a clear and satisfactory explanation of observed phenomena. From this over-confidence in the power of the chemist to explain everything, there has been a natural, and doubtless wholesome, Experience has shown that, reaction. great as the value of a knowledge of the chemical composition of a piece of metal may be, it is, after all, only a part of the knowledge we need before we can determine with what we are dealing.

To some extent, coincident with this rapid progress of chemical investigation, and within even a shorter period, we have seen the development of the physical test, with the aid of appliances which have attained marvelous perfection in

surprisingly few years.

Thomas Tredgold, in his "Strength of Cast Iron," published in 1823, says: "Lord Bacon's idea of a mechanical history, which Diderot attempted to realize, is not so well calculated to fulfill his own views (concerning the advancement of the arts) as a well-directed course of experiments on the nature, forms and properties of materials. . . . In chemistry much has been done, but an experimental school of mechanical science remains to be formed." Referring to the necessity for more knowledge of physical properties than was at that time possessed, Tredgold says: "The manner in which the resistance of materials has plays the violin, we could have some been treated by most of our common music evenings. If you can suggest a mechanical writers has also, in some man who combines these qualifications I sense, misled the practical men who are

desirous of proceeding upon sure ground, and has given occasion for the sarcastic remark that the stability of a building is inversely proportional to the science of the builder.

Coulomb, in 1784, made some important experiments on torsion, and was probably among the first to study the effect of continued stress upon the elastic limit of iron and steel. In 1818 Wilson estimated the power required to crush cast iron at 2,240,000 pounds to the cubic inch. Reynolds, quoted by Wilson, recorded an experiment in which a cube of cast iron one-fourth of an inch square, re quired 448,000 pounds to crush it. Tredgold considered it necessary to correct these erroneous estimates, and made numerous experiments with cast iron, testing specimens by static loads and under a drop. The results are given in the He also made work before mentioned. some experiments upon wrought iron, correcting or verifying the results reached with crude methods by various European experimenters between 1758 and 1820. The modulus of elasticity of steel was probably first calculated by Dr. Thomas Young, about 1820, from the vibrations of a tuning fork. The height of a modulus found by this method was 8,830,000 feet, and the weight per square inch was 29,000,000 pounds. That is, a bar of steel 8,830,000 feet in length, and 1 inch square in cross section, would stretch from its own weight to double its original length; and its weight, 29,000,000 pounds, is the modulus of elasticity as ordinarily expressed.

It is within a century that the work of Navier, Perronet, Poleni, Telford, Brunel, and others furnished the basis for a more or less exact knowledge of some of the tion of the views previously held by enmore easily recognized and described gineers as to the physical characteristics physical properties of iron and steel. of materials, especially of steel. Naturally the results reached by these investigations tended in a material deexperimenters were as incomplete, and gree to popularize experiments with conin many instances as mistaken, as their struction materials in the testing mamethods and appliances were rude and chine, and created a demand for such unsatisfactory. Drop-hammers, single machines, and for accessory apparatus lever testing machines and hydraulic for measuring elongation, etc. The presses were the only power appliances Messrs. Fairbanks were, I believe, the employed in testing during the first half first to produce, in 1863, a testing maof the present century. Experiments chine on the multiple-lever principle, and were mostly directed to ascertaining the though of limited capacity, this was an tensile strength of materials, chiefly iron, important improvement upon previous steel and wood, under shocks or stresses constructions. They were quickly folwhich, at a single application, would prolowed by Riehlé Bros., whose testing ma-

duce rupture. The breaking point thus ascertained was termed the ultimate strength of the material; and, until very recently the data thus gathered were the only bases for calculating the dimensions of members which were expected to resist tension. Resistance to compression was similarly determined by the application of crushing loads to cubes of unit dimensions; and this was deemed satisfactory until the experiments of Hodgkinson demonstrated the previously unrecognized influence upon resistance to compression of the ratio of diameter to

length in test specimens.

Among the earlier of the experimenters in this field, Navier is entitled to special prominence. He probably did more than any one else to bring science and practice together, and to make one help the other. Navier's theory of rupture under transverse strain, though since found to be correct only within certain limits, is still quite generally accepted as a basis for calculations dealing with such strains. To Woehler, in 1858, we are indebted for a knowledge of the influence of the repetition of quiescent stresses. This led to the formulation of Woehler's law, that rupture may be caused by the frequent application of stresses, in no instance approximating the original ultimate strength of the The recognition of this law metal. established the significance of the elastic limit in the calculation of dimensions, and marks what is probably the most important epoch in modern methods of dimensioning.

In 1862, Kirkaldy published his "Results of an Experimental Inquiry, etc.," which effected a considerable modifica-

mation of experimenters. cording torsional testing machine. progress continued until it culminated in the Emery testing machine, probably the most remarkable instrument of precision ever built, and the most improved type of which dates no further back than 1880. In the line of automatic recording apparatus the latest form, devised by Abchine accessories.

by the testing machine. tory fully abreast with the chemical la-lumber and the sundry materials he boratory, and each has given to work makes use of in construction. If he knew othewise have possessed. But he who his materials he could build nothing. should undertake the study of iron and steel with no other light than that which What it shows is, to a greater or less analysis and test can give him, though he extent, dependent upon what the operahimself baffled at every turn by mysteries how, on the one hand, by sudden shock cannot solve. steel. In my experience, very few of any recognized standard; and how, on those who make or use steel are pre- the other hand, by gentle increments of pared to accept the statement that chemistress through lengthening intervals of cal analysis alone can be relied upon to time a piece of metal may be coaxed to determine its quality. It may be broadly show test results far above its real value, stated that certain compositions never and apparently inconsistent with it chemmake good steel; but the reverse cannot ical composition. But even when it is be asserted with equal confidence. With possible to have such confidence in a a given composition the result depends physical test as can only result from a the ingredients. Imperfect melting will with it has been honest and fair, and surgive an unsatisfactory product, no matter rounded by safeguards against every what the stock used or the composition known source of error, we must look elsemethod of accurately determining the testing machine reveals. If we seek to stock from which steel is made as chemidespairing conclusion that one or the

chines still hold a high place in the esti- cal analysis can give us, there still remain The next a great many uncertain factors in the great step forward was marked by the equation of quality. In fact, it seems production of Thurston's automatic re- that the value of ingot analysis may eas-The ily be very much exaggerated, and that within certain limits the physical structure of a piece of metal is quite as important to be known as its chemical composition. There are many gentlemen in this audience who could substantiate, by the results of long experience, the broad statement, that without good melting bott, illustrates the high development at- and proper subsequent treatment of the tained in the construction of testing maingot, good steel is impossible with any admixture of ingredients which the chemist The period from 1850 to 1875 was, may prescribe. Chemistry has its limitawithout doubt, the most fruitful in additions—not quite sharply defined, perhaps, tions to our knowledge of the physical but still evident. If the chemist should properties of iron and steel as revealed ever succeed in giving us a report show-It comprised ing the exact proportion of each constitthe investigations of Navier, Fairbairn, uent of a piece of metal, beyond ques-Woehler, Spangenberg, Kirkaldy and tion or doubt, we might still be in the Thurston. The work of these and other work before us where the builder is investigators, brought the physical labora- when he stands among his bricks and done in the other a value it would not nothing more than the count and tally of

Nor is the testing machine infallible. would learn much of value, would find tor seeks to have it show. We all know which these methods of investigation applied to a specimen under stress, it This is especially true of can be made to give results far below primarily upon the perfect admixture of a knowledge that everything connected shown by analysis of the ingot. It will where than to the chemist for an explanaalso be questioned by many whether a tion of many of the phenomena which the oxide of iron in steel would materially compare the results of physical and increase the confidence we should feel in chemical test we shall become hopelessly a judgment of quality from analysis. It confused. Generalizations warranted by is true that chemical methods are becom- one relation of composition to qualify ing more rapid and accurate every day; will often be contradicted by a different but with as complete a knowledge of the relation, and we should reach the almost as the sole standard by which to judge quality. Which we should choose would depend upon whether we had formed our opinions in the laboratory or in the mill.

To harmonize what seem to be the often-conflicting results of chemical analysis and physical test, we must seek for a knowledge of causes affecting quality in yet other directions. In this we have already had assistance of the greatest The anomalies developed by the steels made by different formulæ, and of that the quality of steel does not alone

depend upon what it is made of.

iron-clads was begun at Brest and their construction. Lieut. J. Barba, Chief Naval Constructor at L'Orient, investigated some of these anomalies, and to him we are indebted for the first exact observation of the effect of manipulations upon steel. Barba's work was ably supplemented by that of Joessell, and continued by Pourcel, Holly, Metcalf, Hill, and others, with the result of showing that the influence of manipulation in processes of manufacture is of prime importance in its relation to the quality of the finished product. important to know the chemical composition of muck-bar and ingot, but experiment and experience have shown that the beam, the rail, the ship-plate and the bridge-member on which the safety of the whole structure may depend, may be so far below the standard of quality which analysis would lead us to expect, or physical tests of specimens taken at intermediate stages in the process of manufacture warrant us in assuming, that we must seek still further light on the subject in the revelations of microscopic analysis.

In the microscope we have an instrument which promises to supplement the laboratory and the testing machine, to harmonize their seemingly conflicting records, and to detect the influence of shop treatment at every step in the pro-The work of the cess of manufacture. microscopists who have thus far turned their attention to iron and steel, has not sult.

other of these methods must be accepted been complete enough as yet to give us more than a few standards by which to compare our observations, but I do not doubt that within a very few years the microscope will give the laboratory and the testing machine a value for the ironmaster, the steelmaker and the engineer incomparably greater than that they now possess. This branch of special investigation is one which offers many attractions for the conscientious student who will approach it in the earnest spirit of scientific inquiry. Within the little circle of the field of a microscope, there is samples of a given composition taken at more to be learned of value to science different stages in the process of manuand the arts than the chemist can prefacture, has called attention to the fact dict or the physicist explain. It will bring us to the point beyond which no investigation can proceed. In 1873 the building of three large now, we shall realize that "the utmost still is hid;" but when we shall have L'Orient, and steel was largely used in learned all it is possible to learn from the revelations of the microscope, we shall have followed truth to the limit of human intelligence, and seen it fade into infinite mystery.

> Meanwhile, let us remember how new is our knowledge of iron and steel, how incomplete, and how dependent is the student by one method upon the knowledge gained by other methods, some as vet almost untried. It is too soon for broad generalizations. The key to the mystery seems to lie in the structure of the metal, and until we know more of this, and can reason from effect to cause through the known phenomena of analysis and test, we may safely distrust that assurance of conviction and positiveness of utterance which Tyndall tells us are ever characteristic of the "confidence of half knowledge."

The Japanese are seriously considering the utilization of the hot springs near Tokio. L utilization of the hot springs near Tokio, as a means of producing heat and power. The subject has been discussed in the Japanese Scismologic Society. In a country where the presence of hot springs and the frequency of carthquakes indicate a rapid increase of subterranean temperature, the thing may be quite practicable. In the "Proceedings" of the Paris Society of Civil Engineers it has even been questioned whether the extraction of the heat would not diminish in some degree the frequency and intensity of earthquakes: but if any considerable heat extraction could be effected, exactly the contrary would be the re-

ON THE REDUCTION OF THE GRADIENT ON CURVES.

BY H. P. VINCENT.

Contributed to Van Nostrand's Engineering Magazine.

In the following paper are contained Then there is approximately, the results of an investigation into the nature of the resistance to the movement of trains, arising from curves. The older data, on which it is based, are indeed but "rudely observed facts," as so forcibly pointed out by Mr. Wellington in his celebrated work. There is, however, also a small body of later observations, both published and unpublished, besides my own, of which I have availed myself. Altogether the material is scanty, considering the importance of the subject; and it would therefore be too much to expect a fine degree of accuracy in the resulting formula.

Let Q=number of horse-powers developed by the locomotive in taking a train at uniform speed up any grade—provided that grade be perfectly straight.

> P=number of horse-powers developed by the locomotive in taking the same train, at the same uniform speed, up that same grade --provided that grade be all on a curve of the degree d.

d = degree of curve.

n = total number of cars (locomotiveand tender included) which constitute the train under consideration.

L=total length of that train.

k = coefficient of curve-resistance: not to be confounded with the coefficient of friction. The coefficient of friction for the different materials have been ascertained under the condition, that the pressure should never become large enough to cause noticeable abrasion. But it is the very nature of curve-resistance to cause abrasion.

$$P = \frac{(1+t^{n+1}-(1+t))}{nt}Q \quad \text{where}$$

$$t = \frac{d L}{5730 n}k$$

This formula is based on the car as a unit. Better results, at least theoretically, may be expected from introducing, as a unit, the axle, or even the rigid wheel-base. Whether the practical benefit will compensate for the increased difficulty of the formula I have not, at present, the means of deciding, but intend to consider at some future day.

To utilize this formula for freight service—the only one I shall here consider —for the purpose of finding the grade q(in per cent.) which, combined with the curve of degree d, shall consume the same power as the tangent grade G (in per cent.), I assume the total resistance of the train on straight and level track, for the usual speed of trains (10 miles per hour) as 8 pounds per ton (@ 2,000 lbs.) of the weight of train. This resistance is greater than the so-called rolling friction of the train. The former is the measure of the work performed by the engine; the latter alone taxes the adhesion. The object here to be obtained is to equalize, not merely the external resistances, but the total work of the engine. This value is but an approximation by Clark's data. There are other formulæ, more complicated, but scarcely more trustworthy. Nothing can give accurate values but an extensive study of indicator diagrams taken under the carefully ascertained conditions of actual traffic.

With this assumption there is

$$g = (G + 0.4) \frac{nt}{(1+t)^{n+1} - (1+t)} - 0.4$$
 where

$$t = \frac{dL}{5730 n} (0.3 + 0.06d)$$

The value of the coefficient k, as here given, is the weak spot of this formula, for the reasons pointed out in the introduction. Such as it is, it gives fair working results up to 20° or 21° curves. The additional resistance which may be caused by the centrifugal force of the train, is not included. For roads with trains of low average speeds I simply neglect it; and for roads with high average speeds I assume it counterbalanced by the superelevation. In the latter case the use of some kind of transition curve is essential.

L and n depend principally upon the locomotive used; upon the weight of the average car, and upon the weight of its average load. In general, n should be so taken, that the locomotive could just move the train at normal speed from water-station to water-station up the grade under consideration, if it were perfectly straight.

This formula is intended only for the reduction of the grade on curves, which are longer than the train, and for standpler in practice to use the reduced grade off by the usual vertical curves.

on all curves, long and short alike; but on curves shorter than the length L of train, instead of beginning and ending the reduced grade at the nearest station, resp. half-station to the B. C. and E. C., begin and end it at another station, resp. half-station, further on the curve, in inverse proportion to its length.

As an example, I will take the Mogul locomotives of the Southern Pacific Railroad, of 64,000 lbs., weight on the drivers, total weight with tender, about 120,000 lbs, boiler pressure, 120 lbs. per square inch. It can, with certainty, take 20 average loaded cars up a 1 per cent. straight grade at a speed of twelve miles per hour, at a continuous effect of 412 indicated horse-

powers.

The following table shows the grades, which, combined with the curves above them, will require the same continuous effect from the engine, provided that all curves are at least as long as the train. For shorter curves an approximate method has been indicated above; and instead of returning to the full tangent grade for shorter distances than 200 feet, the grade on one curve should gradually pass into ard gauge roads. For shorter curves a that on the other. As a matter of course, formula might also be given, but it is sim- abrupt changes of grades are to be eased

Degree of curve	0	1	2	3	4	5	6	7	8
Grade in per cent	1.000	0.973	0.935	0.888	0.833	0.771	0.703	0.630	0.553
Difference									
	1				!		1		
Degree of curve	9	10	11	12	13	14	15	16	
Grade in per cent	0.473	0.393	0.313	0.235	0.160	0.089	0.023	0.037 descend's	
Difference 80 80 80 78 75 71 66 60									
				}					

differences are increasing at first, are then stationary and finally are decreasing. This is an expression of the fact, that the proximation. It is easy to see, even with- dient, could readily use smaller proporout graphical representation, that about tionate amounts, if so inclined. And

The third line contains the differences a $14\frac{1}{2}$ ° curve on a level would be equivabetween the grades in thousandths of one lent to a straight 1 per cent. grade for the per cent. It will be noticed, that these locomotive here considered, with such weight of average car and average load, as form the basis of this computation.

Any one objecting, that this table value of the coefficient k is but an ap-shows too much of a reduction of the gra-

altogether—use empirical scales, this and corresponding tables might serve as a kind of preliminary guide. For empirical scales can by much hard work be made, which will give excellent results, as experiments carried out on the more recently built portions of the Southern Pacific Railroad amply prove. The grades on curves on this road are somewhat less reduced than the above table shows, but the whole system was undoubtedly designed originally for a lighter locomotive—probably of the Standard American pattern—than the one there largely used now for heavy freight The methods above advocated, however, are not those of the Southern The latter are arithmetically Pacific. more accurate, but also more labori-

It has been objected that this investigation rests upon no basis of experimental fact; that the existing state of knowledge does not warrant the use of so complicated a formula; and that it probably contains a theoretical error.

These objections seem to involve an entire misconception of the meaning of a formula, such as the above. This is, like every other physico-mathematical theory, an attempt to combine and harmonize such observations as are available. indeed very much to be regretted that the same interest is not manifested in the locomotive that has been lately exhibited in the mechanical movements of the horse, for which the wonderful series of experiments in California form the basis of all accurate knowledge. For then we would now have, or might soon expect to obtain, a large body of scientific experiments on the performance of the locomotive. But as there is no immediate hope of this, the best any one can do is to combine and utilize such observations as there are. An apprehension, that this formula contains a theoretical error, is saying but little against it. I think it very likely that it does contain a theoretical error, and would consider it little short of a miracle if it did not. The apparent complication of the formula is nothing against its value, but merely against its convenience. It is in the nature of things that a simple formula cannot be correct. Besides, the former assumption of a reduction of the gradient in direct proportion to the sharpness of

even to those, who—rejecting formula the curve, on all gradients alike does not lead to a *simple* formula for the work performed by the engine, which is after all the fundamental consideration. And less so does the progressive scale given in Mr. That these scales Wellington's work. were never before put into the shape of formulæ does not alter the matter; the mathematical law remains the same, however expressed.

> To compare this subject to another of vastly greater importance—the flow of water in channels. For nearly a century a great number of mathematical expressions for the velocity of flow have been given by different investigators. Which of them is the correct one? There is evidently no correct one; for every one of them, under certain conditions, gives notoriously erroneous results. And when Messrs. Ganguillet and Kutter published their investigation, was the state of knowledge at the time such as to warrant the use of that complicated formula? Nevertheless, very many hydraulicians seem to think that it has helped to advance our knowledge and that it is, in fact, the best in exist-

> In view of this and other similar cases, I have no fear of corrupting the scientific conscience of my fellow "railroad-stakersout" and venture to submit to them my formula with all its imperfections on its head.

> NEW process for working lead fume into litharge and red lead has been described in the "Journal" of the Society of Chemical Industry. The fumes evolved from the working of galena contain lead sulphate, sulphite and oxide, arsenic and antimony, also lead sulphide, and when zinc ores are present, zinc oxide. The lead fume is mixed with sodium carbonate or hydroxide, and roasted. The roasted product is then washed, whereby sodium sulphate and sulphite and sodium compounds, containing arsenic and antimony, are separated. The lead compounds are converted into lead oxide by this treatment. The lead fume may be boiled also with a solution of sodium carbonate or hydroxide, lead carbonate and hydroxide being formed, whilst arsenic and antimony are dis-solved. The washed precipitate is then roasted. In the presence of zinc compounds they are removed by boiling with sulphuric acid. If lead sulphide be present, it is necessary to boil first with a solution of calcium hypochlorite. Sodium sulphate is recovered from the liquors after separating arsenic and antimony.

PRIMARY BATTERIES FOR ELECTRIC LIGHTING.

By ISAAC PROBERT.

From the "Journal of the Society of Arts."

itself," and this quotation was never more appropriate than to the subject that will

engage our attention this evening.

All of us probably know that it was by a primary battery that the electric light was first introduced. So far back as 1802, Sir Humphry Davy, using a battery consisting of plates of copper and zinc dipped into dilute acid, obtained the electric arc between poles of carbon. In the Journal of the Royal Institution for that year, Davy, in describing some experiments on the spark yielded by the newlyinvented galvanic battery, uses these words:-"When, instead of the metals, pieces of well-burned charcoal were employed, the spark was still larger, and of a vivid whiteness." He also pictures an apparatus for, as he says, "taking the galvanic electrical spark in fluids and aeriform substances." It consisted of a glass tube, open at the top, and having a tubular outlet at the side through which a wire tipped with charcoal was introduced, another wire, also tipped with charcoal, being cemented in a vertical position through the bottom.

In the same year, the electric light, sustained by voltaic action, was publicly shown in Paris by the citizen Robertson. Professor Sylvanus P. Thompson, in an interesting communication to Nature, has quoted a passage in the Paris Journal of March, 1802, from which it appears that the experimenter used a voltaic pile of 120 elements of zinc and silver, to each pole of which he attached a carbon. On bringing the carbons into contact, a brilliant spark was obtained of extreme

whiteness.

A few years later, Davy, with the large battery of 2,000 cells, which the munificence of some members of the Royal Institution placed at his disposal, obtained an electric light of a power that has rarely been surpassed, even in our own

Thanks to the kind efforts of our Chairman, one of Davy's original battery

It has been said that "history repeats plete battery, to use Davy's own words, consisted "of 200 instruments connected together in regular order, each composed of 10 double plates arranged in cells of porcelain, and containing in each plate 32 square inches. The battery, when the cells were filled with 60 parts of water, mixed with one part of nitric acid, and one part of sulphuric acid, afforded a series of brilliant and impressive effects. When pieces of charcoal about an inch long and one-sixth of an inch in diameter, were brought near each other (within the thirtieth or fortieth part of an inch), a bright spark was produced, and more than half the volume of the charcoal became ignited to whiteness, and by withdrawing the points from each other, a constant discharge took place through the heated air, in a space equal to at least four inches, producing a most brilliant ascending arch of light, broad and conical in form in the middle."

> The electrician, Children, constructed a battery of twenty cells having huge double plates four feet by two, of which the whole surfaces were exposed, in a wooden trough, in cells covered with cement, to the action of diluted acids. It was the grandest combination ever then constructed for exhibiting the effects of To quote Davy's extensive surface. words:—"Points of charcoal ignited by it produced a light so vivid, that even the sunshine, compared with it, appeared

feeble."

The light obtained by these experimenters was beautiful in the extreme, and naturally excited the admiration and the hopes of the public, or at least of that educated section of the public to whom the advances of science are not unknown; but it was in no way a practical light. The copper-zinc battery used in the experiments was crude, and quite incapable of sustaining a constant current, the carbon points employed for the arc to play between were mere sticks of wood charcoal, which gave an unsteady light and rapidly consumed, and the beautiful regcells is on the table to-night. The com- ulators with which we are familiar, for keeping the length of the arc constant, the devising of methods of ridding the

were then quite unknown.

and transformed into sulphate of zinc by liquid in streams. the sulphuric acid in which the plates are opposed in direction to that of the copzation of the battery is then to considerably reduce the current flowing, and worse than this, the amount of deposited gas varies with time and other circumstances, and the current likewise varies Such a battery, when used to produce the electric light, furnishes a light of constantly varying intensity which is extremely painful to use, and possesses other drawbacks also.

It is evident then that a battery, to be of any use for practical electric lighting, must be capable of generating a constant other qualifications, viz., a high and constant electromotive force and a small and constant internal resistance. It should consume inexpensive materials, and Smee battery was justly esteemed at the should consume nothing when it is pro-time for its great constancy as compared ducing no current. It should be capable with the batteries previously in use. But of being easily cleaned, and of being sup- its constancy, although great in compariplied with fresh materials. It should re- son with that of the other batteries then quire no skilled attendance. Unfortu- known, was still very far from perfect. nately, no battery hitherto invented possesses all the required qualifications.

So long as constant batteries were undrogen gas upon the copper plate, in name, in its first form, in the inventor's ventors naturally turn their attention to own words. They are these:

battery of this objectionable feature. It has just been said that the current Mr. Alfred Smee was very early in the obtained by the battery employed in field; he found that by roughening the those early experiments was not constant. copper plate, the disengagement of the This want of constancy is due to what is bubbles of hydrogen from its surface was called the polarization of the battery— greatly facilitated. The gas, instead of that is, the deposition of hydrogen gas forming a smooth layer upon the copper, upon the copper plate. In the working collected upon the rough portions, and of the battery, the zinc plate is oxidized was discharged upwards through the

On further investigating the subject, immersed. At the same time, hydrogen Smee found that it was not necessary gas is liberated on the surface of the that these roughenings of the surface copper-plate, where it collects and forms should have appreciable size. In fact, a layer of appreciable thickness, which better results were obtained with a muloffers considerable resistance to the titude of small points, from which the transmission of the electric current. It gas could be disengaged as quickly as it also gives rise to an electro-motive force was liberated by the electrolytic action of the battery, than with a few points of per zinc couple. The effect of the polarilarge size, which, although capable of releasing big bubbles, yet permitted the gas to remain on the plate until the big bubbles had been formed by the aggregation of the tiny particles of gas which first appear. He therefore abandoned the copper plate, roughened mechanically, with which his earlier experiments were performed, in favor of a platinum plate, coated with a deposit of very finely divided platinum, obtained by exposing the plate to the action of solution of chloride of the metal, under the influence of the galvanic current. In our own day, current. It should also possess these platinized silver is often, through a false idea of economy, substituted for the platinized platinum.

This was a very great advance. The

Smee's method of eliminating the illeffects of the layer of hydrogen was but a method of removal, and the question known, the electric light remained a sci naturally presented itself to the minds of entific curiosity, but the invention, by inventors whether a method of preven-Grove, in 1836, of his nitric acid battery, tion could not be devised. An answer in gave a fresh impetus to the subject. Of the affirmative was given by Professor J. all the points enumerated, the power to F. Daniell, of King's College, who infurnish a constant current is the most vented a battery which remains to this important. As the want of constancy of day unequaled in constancy. You may a battery is due very largely, although be interested to hear the description of not exclusively, to the deposition of hy- this first constant battery worthy of the

"A cell of this battery consists of a cylinder of copper three and a-half inches in diameter, which experience has proved to afford the most advantageous distance between the generating (that is the zinc) and conducting (that is the copper) surfaces, but which may vary in height according to the power which it is wished to obtain. A membranous tube, formed of the gullet of an ox, is hung in the center by a collar and circular copper plate, resting upon a rim placed near the top of the cylinder, and in this is suspended, by a wooden cross bar, a cylindrical rod of amalgamated zinc, half an inch in diame-The cell is charged with a mixture of eight parts of water and one of oil of vitriol, which has been saturated with sulphate of copper; and portions of the solid salt are placed upon the upper copper plate, which is perforated like a colander, for the purpose of keeping the solution always in a state of saturation. The internal tube is filled with the same acid mixture without the copper. A tube of porous earthenware may be substituted for the membrane with some little loss of power. A number of such cells admit of being connected together very readily into a compound circuit, and will sustain a perfectly equal and steady current for many hours together, with a power far beyond that which can be produced by any other arrangement of a similar quantity of the same metals.

"The surface of the conducting metal is thus perpetually renewed by the deposition of pure copper, and the counteraction of zinc or any other precipitated metal effectually prevented. The minor affinity of the copper for the acid, however, still remains, and such an opposition could only be effectually avoided by the employment of platinum plates, perpetually renewed by the decomposition in the circuit of chloride of platinum; such an arrangement would be perfect, but too costly for ordinary applications.

This battery, the prototype of all chemical depolarizing batteries, is worthy of attentive study. In it the hydrogen, instead of being deposited upon the copper many attempts to practically introduce plate, is oxidized to water by the solution of copper sulphate, and metallic copper in ceeded one another. One of the most place of hydrogen is thrown down upon noteworthy instances of the employment the copper plate. Polarization is thus entirely prevented.

requisite of a battery for electric lighting, the Daniell battery would be admirably suited to the purpose, but it will be remembered that a high electromotive force and a low internal resistance are also essential, and here the Daniell battery fails. The electromotive force of any copper zinc couple is low, and the internal resistance of the Daniell cell is high. The electromotive force might be raised by the device suggested by Daniell of employing platinum in place of copper, and solution of chloride of platinum in place of solution of sulphate of copper, but the expense would militate against the practical success of such an arrangement.

It was reserved for Grove—now the Hon. Sir W. R. Grove, one of her Majesty's Judges, but then Professor of Chemistry at the London Institution—to overcome this difficulty, and to produce a chemical depolarizing battery of high electromotive force, low internal resistance, and employing a comparative cheap depolarizing liquid. Daniell, as we have seen, had appreciated very clearly the advantage of a platinum plate, but his mind seemed so engrossed with his original idea of a metallic solution, as depolarizer, which in decomposition deposit upon the plate dipping into it a layer of the same metal, that the possibility of finding a non-metallic depolarizer does not appear to have suggested itself to him. Grove, however, saw this possibility, and by the substitution of strong nitric acid for the metallic solution, achieved the success which Daniell had vainly sought for. For the first time, the production of the electric light by the acid of a primary battery became possible on a practical scale; and the very year of Grove's invention, the electric light was used for theatrical purposes, at the Opera House, in Paris.

Suggestions by Cooper, Walker, Bunsen, and Archereau, quickly followed, and in the course of a few years the nitric acid battery had assumed its present convenient form.

It would be tedious to tell you of the the electric light which now rapidly sucof this battery is the electric lighting of the Cherbourg Docks, during their con-If constancy of current were the sole struction in 1858, whereby 1,800 men

were enabled to work during the night, question, we must consider the relative when work must otherwise have been sus- cost of zinc and coal, their thermal equiv-

pended.

In 1831, Faraday made the important discovery that when a closed circuit of conducting material—a ring of copper, for example—is moved in the neighborhood of a magnet, so that the conductor ful work obtained to the total energy passes from a position of one magnetic generated; the cost of the oxidant of intensity to a position of a different mag- the zinc-air—the oxidant of the coal costnetic intensity, a current of electricity is ing nothing; the relative cost, both origgenerated in the conductor, and that inal and for maintenance of the battery when the conductor is moved, so that a and the dynamo and engine; and the relthan when no current is generated. $_{\rm In}$ effect, this great discovery was that, by the intervention of a magnet and a coil of wire, mechanical energy—the energy of the arm or of the steam-engine—can be transferred into electric energy. Out of this discovery have grown the huge dynamo-electric machines of to-day, which, as generators of electricity for lighting purposes, have almost driven voltaic batteries from the field of competition.

Why is this? Why is it that a dynamo-electric machine should be almost universally preferred to a voltaic battery for the production of the electric light? It is a question of cost—of the relative cost of the two methods of producing an electric current. Let us examine this

point a little in detail.

Both in a voltaic battery and in a dynamo-electric machine, the electric energy is ultimately referable to combustion, or, more strictly, to chemical combustion. In each there is a combustible substance, oxygen or an equivalent substance, to sustain the combustion, and the means wherewith to collect and utilize the energy liberated. In a voltaic battery, the combustible substance is usually zinc, rather in the furnace of the engine that other mechanical sources of loss.

alents—that is, the amounts of heat obtainable by the combustion of equal weights of the two materials; the efficiency of the battery and the engine and machine—that is, the proportion of usecurrent is generated in it, more mechaniative cost of attendance. In the case of cal work is done in producing the motion the battery, there is also the possibility of the utilization of the bye-products to

be considered.

To make the matter quite clear, let a practical illustration be taken. Let it be supposed that a house has to be lighted by a hundred incandescent lamps, each requiring a current of .75 of an ampere urged by an electromotive force of 100 volts. The rate at which energy is expended in each lamp, expressed in voltamperes or watts, of which 746 were equal to a horse-power, will be .75 \times 100, that is 75. The energy expended in the 100 lamps will be at the rate of 7,500 watts, which are equal to 10.05 horsepower. But this, it must be remembered, is the actual rate at which energy is expended in the lamps. The energy that has to be developed by the engine is greater, for no dynamo-electric machine is perfectly efficient, no dynamo machine gives out as electrical energy the exact equivalent of the mechanical energy expended upon it. Let it be supposed that the machine used in our installation has a "commercial" efficiency of 80 per cent., that is, that 80 per cent. of the mechanical energy put into the machine reappears in the external or lamp circuit as electrical energy, the balance being wasted and the oxygenous substance sulphuric in heating the armature coils, and the acid. In a dynamo-electric machine—or friction of axles, slipping of belts, and drives it—the combustible substance is the rate at which energy is generated by coal, and the oxygenous substance air. the steam-engine must be 10.05 + 1.25, The question, therefore, as ordinarily that is 12.55 horse power. This mechanpresented, resolves itself into this: Re- ical energy is to be produced by the comquired a certain quantity of electric en- bustion of coal, and if all the heat liberergy; can it be more economically pro- ated in the combustion of the coal could duced by burning zinc in sulphuric acid be collected and utilized, the supply of in a voltaic battery, or by burning coal in coal required to generate energy at the air in the furnace of the engine of a dy-rate of 12.55 horse-power would be very namo-electric machine? In answering this small; but, unfortunately, steam-engines,

even of the best make, have but low efficiency, and a horse-power-hour of energy requires in practice somewhere about $4\frac{1}{2}$ lbs. of coal for its production; 12.55 horse-power-hours will therefore require about 56\frac{1}{2} lbs. of coal—say, roughly, half a-hundredweight, the cost of which is not more than 6d. Assuming that the lamps were required to burn for 1,800 hours a year—that is on an average nearly five hours a day—the annual cost for coal would be £45. The prime cost of a suitable dynamo-machine and engine (with boiler) would be, say, £300, the interest on which, at 4 per cent., would be £12, and the annual depreciation, at 10 per cent., £30; the cost of attendance would be about £60, so that the prime cost would be £300, and the total annual cost

£147, or £1 9s. 5d. per lamp. If a galvanic battery is used to supply the current to the lamps, the energy will require to be produced at a rate of somewhere between 10.05 and 20.1 horse-power, for the efficiency of a galvanic battery depends upon the relations subsisting between the resistance of the battery itself and the resistance of the external circuit. When the greater resistance is reduced until it exactly equals the smaller, the greatest possible current is obtained from the battery, but exactly one-half of the energy liberated is wasted in heating the battery. When the external resistance is high, as compared with the internal, the current is less, but the percentage loss of energy is also less. As a matter of practice, therefore, it becomes advisable to arrange the resistances so that the external is greater than the internal, whereby the efficiency of the latter is made to as nearly approach a hundred per cent. as we wish. Let it be supposed that in our installation the efficiency is, as in the dynamo just considered, 80 per cent. To liberate a horse-power-hour of energy, a quantity of zinc must be oxidized equal to 2.022 lbs. divided by the electromotive force of the galvanic couple in use. It is calculaobtainable in any zinc sulphuric acid bat- as the total cost of materials. tery is 2.248 volts, from which, however, a deduction must be made on account of cannot be charged, and then kept in acthe energy absorbed in the chemical action of depolarization. The amount of drop of acid have been consumed. It has the deduction will depend upon the na-

soda and sulphuric acid it is .708 volt, with bichromate of potash it is .343 volt, and with fuming nitric acid .284 volt. In order to do fullest justice to batteries, let it be assumed that strong nitric acid is the depolarizer used in our installation. The deduction to be made from the total electromotive force of the battery is, therefore, .284 volt, and the net electromotive of the battery is 1.964 volt, which corresponds to a consumption of 1.03 lb. of zinc per horse-power-hour of energy. liberate 12.55 horse-power-hours, 12.93 lbs.—say 13 lbs.—of zinc must be used. If the price of zinc be taken at 2½d. per lb., the zinc used per hour costs 2s. 81d. But the expense does not end here. Air, the oxidant of coal, costs nothing; whereas sulphuric acid, the usual oxidant of zinc, is of considerable value, costing, even on the commercial

scale, \frac{3}{4}d. per lb.

To oxidize a pound of zinc, $1\frac{1}{2}$ lb. of sulphuric acid is required, as is shown by the equation, $Zn + H_0SO_4 = ZnSO_4 +$ H_{\circ} . To oxidize 13 lbs. of zinc, $19\frac{1}{2}$ lbs. of acid are therefore required, which costs 1s. $2\frac{5}{8}$ d.; this, added to the cost of the zinc, makes about 3s. 11d. But we cannot stop even here. In order that the zinc may give the greatest possible return of energy, the electromotive force of the voltaic arrangement must, as has been stated, be high, and this—as a net result, at least—can only be obtained by the aid of a good depolarizing liquid. We assumed ourselves to be using strong nitric acid, and if we suppose that the average effect of nascent hydrogen upon this substance is to produce nitric oxide (N₂ O₂), the amount of acid required will be shown by the equation 2 HNO₃ + 3H₂ (equivalent to 3 Zn)=N₂ O₂ + 4 H₂ O. It follows, therefore, that the solution of every pound of Zn is accompanied by the deoxidation of $\frac{2}{3}$ lb. of nitric acid. In the production of 12.55 horse-power-hours of energy, 82 lbs. of nitric acid will therefore be deoxidized, the cost of which, at 6d. per lb., is 4s 4d. This, added to the cost ble that the highest electromotive force of zinc and sulphuric acid, gives 8s. 3d.

But we have not yet done. A battery tion until every grain of zinc and every been found by experience that no more ture of the depolarizer: with nitrate of than about 20 per cent of the acid can

be utilized. When this proportion has process of "refreshing" it is possible to Next, contrivances may be adopted by completely exhaust the acid solution, let which the solutions are more completely materials per hour is 8s. 3d., and assum- arts. ing, as before, that the light will be retaken at £120, the interest, at 4 per cent., substance is now before the public. on which is, say, £5, and the annual determine. Primary batteries have as yet been replaced, among other substances, no records of experience whereon to base by Mr. Ross. an opinion. It is claimed by the inventors of attendance is so small as to be negligi- al in a state of chemical combination,

(that is £759 10s.) by the number of likely to afford any profit to the person lamps, the annual cost per lamp is found using the battery. to be £7 11s. 8d., as against £1 9s. 5d., never possible to completely use the acid cally so-called) from the Daniell's, which solution.

the cost of the light as produced by a cells. battery.

In what way is it possible to reduce the been used, the battery begins to flag, and cost of electric lighting by galvanic batis soon of no further use for electric teries? It is evident that there are four lighting until the solution has been ways open; and invention has been acchanged. The greater part of the acid is tive in all. In the first place, a cheaper thus removed as spent solution. But oxidizable substance than zinc may be neglecting this source of waste for the employed; and in the second, possibly a moment, and assuming that by a careful cheaper oxidant than sulphuric acid. us see what the cost of our 10.05 horse-exhausted; and lastly, the bye-products power is when generated by a galvanic —the substances formed during the acbattery. We have seen that the cost of tion of battery—may be utilized in the

In the first place, as to the oxidizable quired for 1,800 hours a year, the annual substance:—Zinc is almost universally cost for materials only is £742 10s. 0d. employed, but lead and iron have been The prime cost of the battery may be suggested, and a battery using the latter

Next, as to the oxidant, or, speaking preciation, at 10 per cent., is £12. The more generally, the solvent of the positive cost of attendance is very difficult to de-element of the cell:—Sulpuric acid has been used for electric lighting to such a by hydrochloric acid, and the battery emsmall extent, that there are, practically, ploying this liquid has been introduced

As to the bye-products, little can be of batteries that the cost is very small; said, except that the less said the better. they say that no skilled attendance is re-Some promoters of patent batteries make quired, and this seems reasonable; and a great point of the value of the bye-prothat there is nothing further to do than ducts of their batteries, but, as a matter might be done by a domestic servant in of fact, their statements on this point will the ordinary course of his duties. Let us seldom bear investigation. A zinc residue assume that this is so, and that the cost contains a certain percentage of the metfrom which it has to be recovered by a If we divide the total annual cost somewhat costly process, and one hardly

It may be interesting to notice that, in when a dynamo machine is used. The the Telegraph Department of the Postdifference is great, but it becomes even office, no residues are thought worth pregreater when we remember that it is serving except the "black mud" (technicontains a very large percentage of pure From what has been said, it will be copper in the metallic state. Last year gathered that, in a comparatively large there were 69,323 Daniell cells in use, and installation such as has been sketched, the sum realized by the sale of the year's primary batteries have little chance of "black mud" was £167 14s., or rather success; but for smaller installations, of, more than a halfpenny per cell per year. say, ten to twenty lamps, there may, per- An idea may be formed from these figures haps, be a field of action open to them. of the magnitude of the sum likely to re-Few people occupying a house requiring sult from the sale of the zinc residues—so few lamps as this would incur the which in the Post-office are thrown away trouble of a dynamo and engine, although as worthless-in the case of an ordinary for health's sake they might not object to householder using some ten or twenty

During the past few years, several bat-

divided into two classes; those in which this very disagreeable acid is avoided. the liquids are kept in motion, and those in which they are allowed to remain in a state of quiescence. Of the latter, one of the most important is that devised by Messrs. Holmes and Burke. A description which these gentlemen have been hour horse-power. good enough to furnish reads thus:-

charged or discharged at two operations, by means of a system of siphons formed cells. In order to charge the battery it is only necessary to fill a wooden measuring vessel with the exact quantity of fluid necessary to run into the battery, to connect this vessel with the long leg of one of the siphon systems, and to raise the vessel to a certain height, when the liquid immediately distributes itself amongst the cells, and is bound to attain a uniform height in each of them. To discharge the battery, it is only necessary to reverse the process.

"The fumes are collected and suppressed. The porous pots are sealed into wooden covers, which contain passages for the escape of fumes. The passages communicate with one main pipe formed in the substance of the cells, and the fumes can thence be led away to the fume box, where they are either dissolved or chemically absorbed, according to cir-

cumstances.

"The connections between the cells are so simple that they never can be coupled up wrongly, and they are placed beyond the reach of injury by acids or fumes. They never require disconnection when the battery is discharged or re-charged. They require partial discontwo months without re-amalgamation.

rent of nitric acid in the porous pot. The outer cells are filled with solution of

teries especially designed for use in elec- The hydrogen entering decomposes the tric lighting have been devised; and the nitrate of soda by the aid of the acid, inventors of the more important have forming sulphate of soda and nitric acid. been good enough to bring their batter. The liquid is of very good conductivity, ies here to-night, or to furnish descrip- and as the nitric acid is only formed as it tions of them. These batteries may be is wanted, the inconvenience of handling

"The cost of the liquid is only 5½d. to 6d. a gallon. Each gallon furnishes from 750 to 800 ampere-hours of electricity at an electromotive force of 1.92 volt—i.e., about 1.536 watts, or very nearly two

"The internal resistance of the battery "Each battery of eight cells can be is very low for a primary cell, and equals

.02 ohm. as nearly as possible."

It may be added that, like the generalpartly in the substance of the outside ity of electric lighting batteries, the batteries of Messrs. Holmes and Bourke employ carbon and zinc as the elements.

> The battery which next claims attention is that of Mr. O. C. D. Ross, of which a model is on the table. The chief point of novelty distinguishing it is the ingenious arrangement for charging and discharging the depolarizing liquid.

The battery itself is enclosed in a box, about 1 ft. square by 7 ft. long, which contains thirteen double cells, the plates in each of which weigh about 10 lbs.; the whole box when charged weighs about 2 Each cell contains two carbon plates (formed of $\frac{1}{2}$ in. carbon rods placed side by side) which are immersed in dilute hydrochloric acid mixed with onesixth of its bulk of a mysterious compound, called by Mr. Ross "Eureka," but which might doubtless be replaced, without materially affecting the action or the cost of the battery, by nitric acid. The zinc plates dip into a solution of common salt, the liquids being kept apart by porous partitions. The mechanical arrangement by which the carbon cells are filled and emptied is very simple; a horizontal pipe connected by flexible tubes to the bottom of each inner cell is raised or nection when the plates have to be amallowered; one end is attached by a flexigamated, but the latter, when once thor- ble tube to a cask of acid, and the other oughly amalgamated, hardly ever require end is led to a waste tank. When the re touching. Plates have been run for horizontal pipe is raised, and communication with the waste tank cut off, the acid "The depolarizing liquid is cheap and flows, on turning the tap of the acid easily handled. It is made of nitrate of cask, into the inner cells. When spent soda dissolved in solution of sulphuric liquid is required to be removed, the horacid of a particular strength. It depends izontal pipe is lowered, and the liquid for its action on the formation by the cur- flows from the cells to the waste tank. lution into a groove extending the whole length of the box, and connected by side passages with the cells.

The Ross battery has been examined by Dr. Hopkinson, who reports that:—

"Comparing this battery with others, a great deal may be said in its favor.

"Its constancy with a large current is

remarkably good.

"The liquids used in the cells are less expensive than in any battery having any pretence to constancy.

"Mr. Ross's method of drawing off and replenishing the liquid is very con-

venient."

The electromotive force per cell is stated to be 1.82 volt, and the resistance

Another battery, introduced some time back, is that known as the "Edeo" or "Heap" battery. It is a carbon-zinc couple using bichromate of potash as the depolarizer, and dilute sulphuric acid as the excitant. The cells are lined with lead, and hold each 1 gallons of the bichromate mixture (which can be purchased ready prepared at 1s. per gallon). The zinc plates are 10×6 inches, and so offer a total surface of 120 square inches to the action of the acid; they weigh 3 lbs. each. The electromotive force is stated to be 2 volts per cell, and the resistance 0.2 ohm. The point of novelty is claimed to lie in the preparation of the bichromatic solution, the description of which is best given in the They are as manufacturers' own words. follows :---

"In each lead cell pour six pints of water, and in each repeat the following operation:

"Fill the colander (which is supplied with the battery), with bichromate of potash, and hang it in the cell so that the crystals are just immersed in the water. Pour about one-fourth of three pounds of sulphuric acid over the crystals in the colander slowly, stopping occasionally when the liquid boils. As fast as the bientirely cool, it is ready for use. . . . ous conductors of incandescent lamps. It

salt, in one operation, by pouring the so- This fluid will last twice as long as the fluid ordinarily supplied."

Mr. Heap is good enough to exhibit a three-cell battery in action to-night.

In the other or circulating class of batteries there is one deserving of notice. It is the invention of Messrs. Oliphant, Burr, and Gowan. It is a two-fluid bi-chromate battery, having zincs coated with an extremely thin film of gold before amalgamation. The exciting liquid is a solution of salts of mercury. The liquids for the outer jars and inner porous pots are pumped out of separate tanks into distinct pipes communicating with the first jar and the first porous pot. They then rise up siphon pipes into the adjoining cell, and flow onwards in this way through the whole series. To avoid any possible stoppage through friction in the pipes, it is advisable to have the first cell half-an-inch higher than the second, and so on. Thus, in a series of six cells, the last cell will be three inches lower than the first. The last jar and porous pot are connected to their respective tanks. The tank holding the bichromate solution is fitted as a cell, and works a Griscom or other motor, which causes two small pumps to keep the liquids in constant circulation. The pumps raise two cubic inches of liquid per stroke, and work at the rate of thirty strokes per minute. The pumps are constantly at work day and night, whether the battery is in use or not.

The effect of gilding the zincs before amalgamation is, it is stated, to materi-

ally decrease local action.

Many other batteries might be described, and it may be interesting to note that, during the past three years, about 150 patents for improvements in primary batteries have been applied for in Great Britain alone.

A question which presents itself in connection with the problem of economical lighting by primary batteries is this: Is it not possible to effect economy in the lamps—to so improve the lamps that a given expenditure of energy on the part chromate of potash gets dissolved, add of the battery will develop more light in more, and continue pouring in sulphuric the lamps than is now obtained? Yes; acid as before, until there are used up for it is possible. It would be troubling you each cell all of one and a-half pounds of too much to enter here into a lengthy bichromate of potash, and three pounds account of the scientific principles which of sulphuric acid. When the liquid is should guide the designer of the lumin-

must suffice to say, that the ideally per- which is an important point worth bearfect conductor would assume a spherical ing in mind. Messrs. Woodhouse and form; its mass would be very small, and Rawson have quite recently introduced a its surface also, and the material of new lamp, which they call their "hair filwhich it was composed would possess the power, possessed unfortunately by no tremely thin, hair-like filament, whence known substance, of enduring without their name. No particulars of the change for an unlimited time the passage method of manufacturing these filaments Ōf of a very powerful electric current. all substances hitherto used for incandescing conductors, carbon obtained by the intense heating of a pure hydro-carbon is the best. It will give a greater returning light for a given expenditure of energy, and will withstand the action of the conductor longer than any other substance. It will become possible, therefore, by its aid to approach more nearly to the ideally perfect form of luminous conductor than we should otherwise be able to. If also we can so fashion the intimate structure of the carbon, that the particles already have that arrangement which they tend to assume under the action of the current, the type of perfection can be approached even more nearly. This has been done. In a patent obtained in November, 1882, by Messrs. Boullon and Soward, in conjunction with myself, a method was described by which luminous conductors can be obtained of pure deposited carbon formed under the influence of the electric current. By suitable means, these conductors can be obtained of any required degree of approximation to the theoretically perfect form. What thickness they will ultimately assume it is impossible yet to say. The shorter and finer they are made, the greater is the economy, but the shorter is their life. The thickness at which the economy in action is just balanced by the increased cost of renewal of lamps is the practical thickness, but this can only be determined by lengthy experiments, which are still in progress.

It may be noted in passing that high resistance luminous conductors—and they can be made without difficulty with a resistance of 1,000 ohms and upwards to the inch—have the great advantage that they work with a small current, although they necessarily require a somewhat high electromotive force. This enables the copper leads to be much thinner, and therefore less expensive, than in the case of a low resistance luminous gratification to us to know that the order conductor, worked by a large current, been placed with an English firm.—Iron.

have been published, but it appears that, like the filaments of my colleagues and myself, they are made of deposited carbon. The method of their preparation is carefully kept secret, doubtless for fear of piratical imitations which, although generally easily detected, are yet often hard to prove in a court of law. These filaments are stated to be very efficient. It is said that they will furnish a given amount of light with less than half the expenditure of energy necessary to furnish the same amount in an ordinary thick filament. This is doubtless true: the experiments of my colleagues and myself with our own filaments perfectly support this statement, and we have had the opportunity of experimenting with filaments of much greater length, and therefore light-giving power, than Messrs. Woodhouse and Rawson seem to have had, if a conclusion may be formed from the lamps before the public.

ament lamp." These lamps have an ex-

THE RECENT DANISH ARMOR PLATE TRIALS.— Rarely have experimental tests of armor plates been more closely watched, or followed with greater interest, than those which have lately been concluded at Amager, near Copenhagen. The principal reason for the attention thus exhibited will, no doubt, be found in the circumstance that, whereas most naval powers have definitely settled the question as to the system of armor to be adopted, the Danish Admiralty decided not to be governed by for-eign official reports, but rather to judge for themselves respecting the merits of the only principles of armor plate manufacture at present in use, viz., the French steel plates and the English compound plates. The question has now been decided in favor of Wilson's compound armor, and the order for the armor plates for the Ivar Hvitfeldt has been placed with Messrs. Cammell & Co., of Sheffield. This solution of the question will not surprise those who have followed the various stages of the trials as reported in these columns. Yet it must be acknowledged that the Danish Naval Commission have had to contend with unusual difficulties in arriving at a conclusion, for it was known from the first that the Amager trials, instituted as they were, on an independent basis, would have important results. It is a source of gratification to us to know that the order has

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THE METROLOGY OF THE GREAT PYRAMID.

"Who is this that darkeneth counsel by words without knowledge? Gird now thy loins like a man, for I will demand of thee, and answer thou me.

Where wast thou when the foundations of the Pyramid were laid?

Declare if thou hast understanding.

Who hath laid the measures of its base, if thou knowest?—Or who hath lifted the plumb line against it?

Whereupon are its socket stones made to sink?—or who hath laid upon it the headstone thereof?" Paraphrase of Job xxxviii. 4, 6.

BY LIEUT. C. A. L. TOTTEN., U. S. Army.

Written for Van Nostrand's Magazine.

Great Pyramid of Gizeh was built as an intentional exponent of cosmic truths, have lately had occasion to hail with a certain degree of satisfaction the advent of a new literary effort to put their case upon a more defensible position. In a reprint from the School of Mines Quarterly, entitled, "The Imaginary Metrological System of the Great Pyramid of Gizeh,"* President Barnard, of Columbia College, has renewed the attack upon the Pyramid, somewhat after the manner of host of opponents are hurrying into Professor Proctor, and somewhat upon a line which he considers new, and hence deems to be a theory of his own. Taking, however, a similar stand to that not a little strange, too, that the mystery originally occupied by Prof. Proctor, the greater part of President Barnard's rhetoric is expended in ridicule and denial.

But mere ridicule is a dangerous weapon. While, indeed it is barbed and pointed, its unbalanced shaft is so utterly devoid of fledging that the archer can never be certain what will be the point of fall to its erratic trajectory. The halfmade arrow may return upon the very one who gives the wing to its uncertain flight. Nor is mere denial a potent weapon of defence in an argument of such magnitude as the one which now surrounds the subject of the Great Pyramid. Not only is it an unscientific method, for it will not turn a standing beam, but it is beneath the dignity of those who enter into a public debate upon a scientific subject. We broadly claim that the unsupported employment of these two weapons—ridicule and denial—in the discussion of a subject of such magnitude as that which deals with the origin and object of the Great Pyramid, is equiva-

The opponents of the theory, that the lent to relying upon a pointless stick as a weapon of offence, and upon a paper circus hoop as shield against riposte. The argument has long ago been lifted from the dust of such an arena, and demands the skill of trained and well-equipped contestants.

That the subject is really one of magnitude, of scientific import, and of vast and growing interest, is borne out sufficiently by the fact, that it has begotten such a controversy as it has, that such a print, and that now, not a year passes in which each side of the controversy does not swell its teeming library. It is of the subject increases under the penmanship of every one who writes a book upon it. Prof. Proctor's hostility to what he opprobriously termed the "Religious Theory," led him to the attack. Convinced at last of the weakness of mere ridicule, and awakened to much of the undoubted scientific teaching of the monument, he was forced to offer some explanation for facts monumentalized therein too boldly to be simply the results of accident and coincidence. Hence he propounded a theory of his own, and named it an "Astrologic Theory." The fact is, one cannot devote himself to this topic without at last being convinced of the certainty of Promethean design in all its lines and proportions. Hence, if unwilling to adopt theories already advanced, or if committed, as President Barnard undoubtedly is, in being also the President of the French Metrical Bureau, to a newfangled metrology, to which the Pyramid theory is inimical, the only resort for those who come to the topic, and at length become absorbed by it, is to propound a new theory of their own. This,

^{*} Reviewed briefly in the August No., p. 174.

as just remarked, is exactly the case of upon a road where careful surveyors have President Barnard. Unwilling to accept already erected numberless and sufficient. openly, even the purely scientific theory guide posts. of the monument—a theory which Petrie himself does not dispute—he states that scope of this topic cannot but arise from if the Pyramid is really "a π Pyramid, the perusal of President Barnard's paper as it undoubtedly is, it is so by ac- with a feeling of dissatisfaction that, after cident." So, too, throughout his discus- all, he has introduced into the "Battle of sion of the monument, every cosmic fact the Standards" no new forces, and in realor ratio which we meet is declared to be ity has failed to rally even those already an accident. Nevertheless, waxing warm put to flight. The whole argument of at length in his subject, even the Presi- design based upon the exquisite harmony dent of the Metric Bureau cannot resist of the monument, a harmony which perthe tendency to theorize, even if it only vades and connects each chamber and be in ridicule, and so he propounds a passage with every other, has no weight "Lunar theory connected with the wor- whatever with President Barnard. ship of Isis."

President Barnard's information upon pyramid matters, he proposes this theory sarcastically, and in utter ignorance of posely avoided its discussion. the fact that the whole ground he endeavors to ridicule has long ago been of the mental process by which the covered in sober earnest by Joseph Bax-mind of a candid man is always comendell, F. R. A. S. able astronomer, and a firm believer in the ideas of Prof. Smyth, long ago facts actually built into this monument, noticed all of the lunar references of the length in Mr. Proctor's volume of the Pyramid's solution, a volume which he certainly has no excuse for not having consulted.

The President does not, however, propose his theory in good faith, but in a fantasies, to walk in. He says he does so in the magnanimous hope that in thus ridiculing the whole subject he may at length "induce some of his fellowmen to apply a little common sense to the study of a subject which has been heretofore involved in an elaborate web of ingeniously contrived mysticism."

Those familiar with the dignity and has either escaped him entirely, or else, Unfortunately for our estimate of having no explanation for coincidence, so consummate as to be mathematically beyound the realm of chance, he has pur-

But this harmony is the prime motor Mr. Baxendell, an pelled to recognize design and continuity. Once convinced of the nature of the one might as well doubt it as an architec-Great Pyramid alluded to by President tural reality, as to question the cosmic in-Barnard as his own discoveries, and they tentions of its builder in its due and intihave been familiar matters for years to mately related proportions. Did the evoall well-informed pyramid students. In-lution theory of the School of Science, to deed President Barnard might have which President Barnard belongs, rest found these lunar relations set forth at upon facts as clearly made out as are those built by human hands into this wonderfully proportioned building, there would be no defensible ground for its rejection. But the very scholars who are loath to accept even human intention in the planning of the Gizeh monument, argue despirit of sarcasm and innuendo. He puts votedly in favor of the evolution theory, it forth merely as *moonshine* "for the based upon premises of the same kind, lunatics," who are bathed in pyramid though infinitely less convincing. Their ways are thus not equal. Even Mr. Petrie and Mr. Proctor are forced to admit that an unique system of structure runs throughout this monument, while it is only in a spirit of sarcasm that President Barnard ever does so.

In his discussion of the subject each claim of the believers in cosmic design We do not intend to review this effort receives a separate examination, and at of President Barnard at any great length, the doctor's hands is made to appear simply because to answer all of his head-somewhat out of gear, or to be slightly ings would require a volume much larger at variance with modern scientific esti-than his own. Life itself is far too short mates of the things monumentalized. It to be spent in attempting to set right is as if one denied the existence of a every pedestrian, who is recklessly astray chain, or claimed that its continuity was a matter of mere chance, because its several links were somewhat worn, or bent

with age, and with misuse.

To those who may have an opportunity, and who are willing to examine both sides of this matter for themselves, it will be apparent that President Barnard has by no means weakened the chain of evidence in thus pointing out, here and there, a link misshaped. For besides the argument of continuity, which he does not at all dispute, nor even allude to, there always remains the fact that modern science itself does not certainly know the exact value of any cosmic truth, by means of which President Barnard can pretend to pronounce unerring judgment upon the absolute accuracy of the upon reaching the truth of this monu-known. ment, ever lose sight of the still more astonishing fact that every new and modern calculation of these cosmic data results in a closer approximation to those actually built 4,000 years ago into the monument.

Throughout his book, President Barnard loses no opportunity of frequently reiterating the statement that these ancient peoples could have had no means of determining these facts by actual calculation. He also denies that they knew or even used them in their daily life. To have possessed them would have made them "modern" in every sense of the word, and to have had them and not have used them is preposterous. This, too, is exactly what the Pyramid students them-It is their fundamental selves claim. premise; it is, in fact, the very one of all others upon which the conclusion that the architect wrought wiser than he knew, was inspired—must have been inspired—is firmly founded. For the facts are there, harmoniously disposed, and always occupying middle ground between the extremes of the best modern estimates, and as these estimates converge, upon recalculation they always have the pyramid values round about their mean. Moreover, this pyramid value is always found to be a true "mathematical func-

value is only of modern discovery, and could not have been known to the ancients, yet it is laid out architecturally an hundred times throughout the monument. Was this chance? The modern doctrine of chances replies to us that the odds against a successive coincidence so astounding are in the ratio of one hundred raised to the hundredth power to one. This is unity followed by 102 ciphers, a number past conception, indeed it is a number which is upon the very verge of our utmost powers of enumeration. And yet the π values and harmonies of this monument are few in number compared with the myriad of others linked to them, that reflect and multiply throughout the structure the Pyramid. Nor will the fair mind, bent fundamental facts of every human science

> Let us examine, for instance, a single one of the links which President Barnard claims is bent, and which he therefore would have us believe is not a link, and hence that the chain of evidence is not a chain at all. We can examine any one of them, but as modern science has perhaps studied the Sun Distance with greater care, and at far greater expense than any other question we will select it.

> President Barnard argues upon the Pyramid's reference to this distance, as

follows:

"The article of the Pyramid faith which presents itself for examination next in order is the proposition that the height of the Pyramid is exactly one one thousand millionth part of the mean distance of the earth from the sun. Inasmuch as we do not know the exact mean distance of the earth from the sun, it is impossible to subject this statement to the test of a rigorous comparison; but inasmuch as the builders of the Pyramid knew in all probability a great deal less about the matter than we do, it is next to impossible that the proposition should be true. Supposing it, however, for the sake of argument, to be true, the fact may be accounted for on either of two hypotheses —it is true accidentally, or it is true intentionally. Against the first of these tion," dependent upon the "problem of hypotheses, the probabilities are in the the three bodies," and resulting from its proportion of infinity to zero; and this proper discussion. They were not known alternative, moreover, would be rejected as facts of practical value, or of cosmic with scorn by the disciples of the pyraimport to the world in the day which mid religion. But that the fact may be saw the pyramid erected. The very π true in the intention of the builders, as

knowledge which we have no reason to found unsatisfactory to a skeptical world. suppose them to have possessed. This They have therefore sought for a confirslight difficulty the true believers dispose mation of their hypothesis in comparing of summarily, by taking it for granted the result furnished by it with those dethat their human ignorance was illu-duced from the most recent investigaminated by direct inspiration from on tions of the solar parallax. The orthodox doctrine on the subject, therefore, is that the true dis- distance of the sun has been generally tance of the sun was miraculously made taken to be about 95,000,000 miles. This known to the Pyramid architects, and value has been obtained from the paraltherefore that the height of the structure lax as computed by Encke at Altona, in itself was made, not pretty nearly but, ex- 1822, with data derived from the transit actly the one-thousand millionth part of of Venus of 1769; a parallax which he that distance.

Now what are the facts on which this 95,454,000 British statute miles. extraordinary assertion rests? Simply 1857, Prof. Airy proposed a new method these: In 1867, Mr. William Petrie, hav- for determining planetary distances, ing satisfied himself that the perimeter founded on displacements of Mars in of the base of the pyramid 'has been right ascension, as observed morning and proved to symbolize a year, or the earth's evening from a single station, when in annual revolution around the sun,' and, opposition at its nearest approach to the further, 'that the radius of that typical earth. This method was applied in 1862, circle had also been shown to be the an- by observations made at Victoria, New cient vertical height of the Great Pyra- South Wales, and by others made at the mid, the most important and unique line Royal Observatory, Greenwich, during which can be drawn within the whole the opposition of Mars in that year; and edifice,' was moved by these weighty the results, as computed at Greenwich, considerations to conclude that the same gave a parallax of 8".932, and a distance line 'must represent also the radius of the earth's mean orbit round the sun: and Leverrier at Paris announced (in 1861) in the peoportion of $1:10^{\circ}$, : or 1:1,000, that in order to reconcile discrepancies 000,000: because, among other reasons, in the theories of Venus, the earth and 10:9 is practically the shape of the Great Mars, it was necessary to assume a paral-Pyramid. ceeds, 'notwithstanding, or rather by this is obtained a solar distance of 91,virtue of, its angle at the *sides*, has prace 357,000 miles. Chambers (Astronomy p. tically and necessarily such another angle 3) assumes as a probable value of the at the corners, that for every ten units parallax 8".94, which gives 91,465,000 as its structure advances inward on the the distance. On the other hand, Prof. diagonal of the base, it practically rises Newcomb, in his Popular Astronomy upward, or points to sunshine by nine. says: 'It would appear that the solar Nine, too, out of the ten characteristic parallax must lie between pretty narrow parts (viz., five angles and five sides) be- limits, probably between 8".81 and 8".86; ing the number of those parts which the and that the distance of the sun in miles sun shines on, in such a shaped pyramid lies between 92,200,000 and 92,700,000 in such a latitude near the equator, out miles.' Furthermore, Prof. Young in his of a high sky.' (Our inheritance in the recent book on the sun, remarks: 'It

and simple common sense, is so gro- 885,000 miles. tesquely improbable, that its possibility

asserted, we must assume for them a lest this a priori argument should be

Since early in this century the mean found to be 8".5776, giving for distance For this building' he pro- lax approaching perhaps 8".95. From Great Pyramid, Edition of 1874, p. 48.) would seem that the solar parallax cannot This is the logic, and the whole of the differ much from 8".80, though it may be logic, on the basis of which a fact is as- as much as 0''.02 greater or smaller; this asserted which, to plain human reason would correspond to a distance of 92,-

Besides the astronomical methods, of can only be defended by clothing it with which there are others not here noticed, the character of miracle. The true be there is one of great scientific interest lievers have not failed, accordingly, to be dependent on the velocity of light. The affected by a sort of painful misgiving time required for a luminous impulse to

reach the earth from the sun is known π pyramid. But in a π pyramid the a single second, we are possessed of all when the base is given, the height is This nearly corresponds to a parallax of 8".81 which would give a distance of 92,876,000 miles.

Now the distance of the sun as worked out on the Pyramid theory is 91,837,000 miles. This is in the neighborhood of some of the astronomical determinations. It exceeds the lowest of them, and falls short of the highest. Prof. Smyth accordingly jumps, in this case as in many others in which a favorite quantity of his same class, directly to the conclusion that because his quantity is neither the smallest nor the largest, therefore it is the center and the border of the land of Ham. true one. But if we consider the judgments of astronomers as to these various determinations, we shall see that the inthis country upon physical astronomy, tions is not so great as half a million.

But there is another consideration is said to be, and appears to be really, a the chain of evidence a disconnected

within about a second or less, so that if height is equal to the perimeter of the we can ascertain how far light travels in base divided by 2π . In such a pyramid, the data necessary to secure a very close unalterably fixed, and cannot have a value determination of the distance of the sun. assigned to it at the caprice of the con-Independent methods for the experiment-structor. Now it is a doctrine vital to al solution of this problem were devised the pyramid religion that the side of the some years ago by Messrs. Fizeau and base shall contain the sacred cubit of the Foucault, of Paris; and one of the other Hebrews as many times exactly as there of these methods has been repeated by are days, integral and fractional, in the M. Cornu in France, and by Lieut. tropical year. The height must, there-Michelson of the U. S. Navy Academy at fore, be that which this supposition de-The results obtained by the mands, and it can be neither more nor experimenter last named, are regarded as less. On the other hand, if the height very closely approaching the exact truth. had been arbitrarily fixed at one one-They give 299,900 kilometers as the ve-thousand millionth part of the earth's locity of light per second; and as light mean distance from the sun, the side of is 498 seconds in coming to us from the the base must have had a value such as sun, we find the solar distance to be 149,- this hypothesis requires; and could not 350,000 kilometers, equal to 92,803,464, have been determined by the cubit and the number of days in the year. It exceeds all the bounds of credibility, it exceeds all the powers of credulity, to suppose that two such entirely independent and inconsistent schemes of construction should prove to be harmonious in their practical results. Such a coincidence is indeed physically possible, but the chance in favor of the possibility is less than one to some millions of infinities."

Thus reasons President Barnard. The falls somewhere among several of the question for discussion is therefore the Sun Distance, as monumentalized by the grand gnomon which stands upon the

It has been claimed by Pyramid students, for 30 years, that the vertical height of this monument bears a direct ferior ones have no standing with them reference to this sun distance, that the at all. Newcomb, our highest authority in circumference described by this height as a radius is not only equal to the square places the probable distance at about perimeter of the fundamental base, but 92,500,000 miles, and Young puts it as that the length of this circumference or high as 92,885,000; while the experithe square base contains as many times ments on the velocity of light, which are 100 axial inches, (i. e., 500 millionths of esteemed to furnish the result most the earth's polar axis) as there are days worthy of confidence, give a result almost identical with the estimate of Prof. only a proof of cosmic design, but one Young. The Pyramid distance is, there- that is most appropriately built into the fore, only about a million of miles too very parts of the monument, where, by short; while, probably, the uncertainty the relations of the three things typified, which still attaches to scientific deduc- and the form of the Pyramid itself, it naturally belongs.

If, however, President Barnard's sarwhich is quite conclusive as to the question now under discussion. The pyramid is more than bent; it is broken, and

But we unhesitatingly reply that this conclusion is absolutely erroneous, and we propose to show it upon his own ground. Let us quote it again and then we will be better able to discuss it. It is as follows:

"The Pyramid distance is therefore only about a million of miles too short; while probably the uncertainty which still attaches to scientific deductions is not so

great as half a million."

Several things are here to be noted. In the first place there is the broad admission that even modern science rises from its most carefully studied problem, and from one upon which all the modern civilized nations have repeatedly united, sparing no expense, still doubtful by perhaps half a million of miles. This best modern deduction places the probable distance at about 92,500,000 British miles, with a probable increment of some thousands, if Professor Young's experiments upon light are fundamentally correct. We shall therefore accept this "best modern estimate" as to the sun's distance, convinced that a problem so faithfully and expensively studied, cannot have been solved with an error that shall ever hereafter cause the result to vary very considerably from 92,500,000 miles.

What now is the Pyramid sun distance? President Barnard is seriously in error in making it out to be the height multiplied by 10 raised to the 9th power. quotes, it is true, Prof. Smyth as his authority, but Prof. Smyth qualifies this statement in that he expressly says that 9 on 10 is only "practically the shape of the Great Pyramid. That is, not absolutely; 9 on 10 is an approximation. It is a wonderfully close and practical approximation, too, and it is one that is nearer the absolute truth than modern science is certain of the distance under discussion, by President Barnard's own admission. For the 9 on 10 theory of the slope places the sun distance at 91,840,011 miles, while that arrived at by modern science after all of its labors is really doubtful after its very first fig-

Now if the Pyramid is a π -Pyramid, as President Barnard admits "it undoubtedly is," it cannot be an exact 9 on 10 Pyramid. The question is therefore to de-—what is the slope of the monument up fore becomes

the arris or hip lines, as they climb, from the fundamental, southeast, socket up towards the vertex of the cap-stone?

This slope is accurately expressed by

the ratio.

Slope of a
$$\pi$$
-Pyramid= $\frac{20\sqrt{2}}{\pi}$ on 10

or carrying the calculations out to 14 places of figures, it is 9.0031631615711+ on 10.

This slope is so very close to the far more simple one, expressed in whole numbers, to wit; 9 on 10, that in common parlance the latter is generally used instead of the more cumbersome though absolutely exact decimal ratio. Either President Barnard knew this, or he did not. say that he knew it would make him out as unfair in argument and scientific investigation, as upon page 22 he implies that Prof. Smyth has been. To say he did not know it is to point out that he has failed to comprehend the nature of the very question he is, with ex-cathedral vehemence, endeavoring to criticise.

Lest it may here be objected that the defining of a pyramid by its slope up the arris line, rather than directly up its face, is a fanciful method, and one without authority, it is to be noticed, that, as the latest measurer, Mr. Petrie, admits, "the designs of the various slopes that are met with, appear to be always a simple relation of the vertical and horizontal distance." It is in this very way that the Egyptian hieroglyphics themselves define them. For Ahmes, in his mathematical papyrus, defines pyramids by their "sloping height up the arris edge, and their diagonal of the base beneath that line" (Petrie): So that the natural and Egyptian method of stating a slope—a question which bears so strongly on the whole planning of the pyramid—is to say that it is built by the

$$\frac{20\sqrt{2}}{\pi}$$
 on 10, template.

This, it will be noticed, increases the 9 on 10 approximation, by somewhat more than the .003th power, and gives us a function without error, and one to which President Barnard dare not advance an objection. With this expression for the termine exactly—I speak mathematically slope the Pyramid sun distance (S) there-

 $20\sqrt{2}$ $S=H(10)^{-\pi}$, in which H is the height of the Pyramid.

Mr. Petrie is the latest measurer at Gizeh, and a disbeliever in most of the Pyramid theories. But, so far from overturning the cosmic theory of the Great Pyramid, as enunciated by Prof. Smyth, Mr. Flinders Petrie's work has magnifi-cently endorsed it. His measurements of this building are throughout so nearly identical with those of Prof. Smyth that they prove the entire honesty of the latter, and fully corroborate all the ratios which he and Taylor originally noted. It was the elder Petrie, his father, who first advanced this sun distance reference. It is not a little strange, therefore, that the son by his measurements should unwittingly and yet so thoroughly support his father's theory, in which he does not believe. The very The very valuable work which details Petrie's labors at Gizeh should be in the hands of every one now engaged upon the solution of this engrossing problem. Especially should the opponents of the cosmic theory read and study it more closely than their own writings show they do. Now the careful measurements of Mr. Petrie enable us to determine the ancient height of the Pyramid from the floor level of the southeast or lowest socket, to the summit of its very capstone. He gives the data as follows:

From vertex to pavement level= $5776''.0 \pm 7''.0$ "pavement to s e. socket level 39 .9

... Petrie's height over all $=5815 .9 \pm 7''.0$

That is, it is practically 5816". with a possible seven inches of doubt in either the positive or negative direction.*

Now if we add less than one half of the margin of error, actually here allowed by Mr. Petrie, to his own height of this ancient monument, we shall obtain the very height always claimed for the monument by maintainers of the cosmic theory. The

height claimed by them is 5818".62+ British inches, which is equal to 5813.01 + Pyramid inches. Each of the latter is $.001\pm$, greater than the present British inch, and is an even 500 millionth of the earth's polar axis.

Expressed accurately by a circular and circummetric function, and for such a

 π -Pyramid this height is

$$\mathbf{H} \! = \! \frac{180. \; \mathbf{A}}{\sqrt{\pi}} \! = \! \frac{32400''}{\pi\sqrt{\pi}} \! \! = \! 5818''.622870 +$$

in which A is the "analytical unit" $(57.29^{\circ} +)$

Let us now treat this height, which from its possibility of exact mathematical expression is absolutely without error, by the equally absolute arris slope of the Pyramid just determined. The function for the sun distance will then be accurately as follows:

S=H (10)
$$\frac{20\sqrt{2}}{\pi} = \frac{32400''}{\pi\sqrt{\pi}} (10) \frac{20\sqrt{2}}{\pi}$$

 $=(5818''.622870+)(10)^{9.0031631615711+}$ but (10) 9.0031631615711+ equals the number whose common modern logarithm is

9.0031631615711 +since the logarithm of 10 is 1. Thence taking the common logarithm of H and adding it to this logarithm we shall have the logarithm of the required height in inches.

Thus,

Log. H = 3.76482020126540135818107 $20 \sqrt{2}$ " $(10)^{\pi} = 9.0031631615711 +$

Log.
$$S = 12.7679833628365$$

 $S = 5861157.....''$
 $= 92,505,634..*$ miles!

This remarkable result, which tallies so closely with Prof. Newcomb's estimated "probable sun distance" (92,500,000. \pm miles), as quoted so sarcastically by President Barnard against the mistaken 9 on 10 approximation, is calculated to hammer at least one link of the chain of evidence into perfect shape upon the anvil of every candid judgment. Nor is there a single one of the points of real pyramidal significance, which have thus again

^{*} Mr. Petrie's measure has thus admittedly a possible error of ±7".0. Upon page 15 of the introduction he says: "The probable error of all important measurements is stated with the sign ± prefixed to it as usual"... And further on he says, "and I will only add a short definition of it as follows: The probable error is an amount on each side of the stated mean, within the limits of which there is as much chance of the truth lying as beyond it."

With these statements, which show the accuracy with which Mr. Petrie accomplished and records his splendid measurements, we are ready to continue our examination of the subject.

^{*} The number corresponding to the logarithm of the result has only been calculated to the seventh figure of the inches, because of the difficulty attending the process. It is calculated far enough however to avoid error greater than unity in the miles.

been disputed and put into controversy by President Barnard that will not yield to the sledge-hammer of mathematical truth,

in this same manner!

It is apparent that the above argument would not be affected in the least by the most extreme refinement of computation. For an error of 200 feet in the earth's polar semi-axis represents 1000 miles or so in the sun's distance, and an uncertainty of a second in the parallax involves about 100,000 miles therein. The pyramid pronounces in favor of a solar parallax of $5''\sqrt{\pi} = 8.''86226925 +$, a number which is ten times the well-known "constant" used for obtaining the equality of squares and circles. This is exhaustively shown by Mr. Chas. Latimer, C. E., in the March (1883) number of the *International* Standard, where he also points out the fact that the base of the Pyramid

$$=100 \frac{81''}{\frac{1}{2}\sqrt{\pi}} = \frac{8100''}{.886226925} = 9139''8712581$$

Now it is a remarkable fact, perhaps more remarkable than any we have yet considered, that the height by which we have just determined the true sun distance, demands for the perimeter of the square indicated by the level of the southeast, or fundamental socket of the pyramid, a measure of exactly

 $4 \times (9139''.8712581 +) = 36559.''4850324$ (Brit. in.)—a distance which reduced to pyramidal inches, or to 500 millionths of the polar axis, is the year number

 $(365.2422) \times 100.$

This number, 9139"8712581+, has always been claimed by modern "pyramid students" as the actual fundamental base side indicated by the Pyramid. It is now proved to be so by Mr. Petrie's splendid measurements, and is shown above to be a true circular and circummetric function. The latest measurer at Gizeh, Mr. Flinders Petrie, claims, however, that the true base of the Pyramid is but 9068.8", in which connection it has been lately remarked; "it had been a fundamental article in the Pyramid religion that the base should measure just 9140 British inches, and as it proved to measure only 9068.8, that with this determination, the beautiful union of the sacred cubit (25.") and the length of the tropical year (365.242) melts away into thin air."

get at the true facts of the case. Petrie's base (9068.8 inches) is that of the Pyramid measured horizontally along the upper surface of the pavement which surrounded it. It is not that of the fundamental square indicated by its lowest or south-east socket level. For reasons of his own, Mr. Petrie has assumed the pavement base as the real one to be studied. It was no doubt set out with most beautiful skill, and with a manifest object as to length. But it is the fundamental square that pyramid students have always maintained as of tropical year significance, and the total height of the monument from this fundamental level up to the vertex of its capstone as of solar distance import.

Upon page 38 of his "Pyramids and Temples of Gizeh," Mr. Petrie admits that "the sockets were cut to receive the sloping face, which was continued right down to their floors beneath the pavement." . . . "Hence the sockets show the size of the Pyramid where it was started from varying levels, which were

all under the pavement."

Mr. Petrie further gives as the measure of the sloping line from the south-east socket up to the north-east socket, the length $9130.8" \pm (?)$. Pyramid students find that rigid mathematics demand 9131"-.05 + -a difference of less than .3''! Now 365.242×25 (that is the year number by that (25) of the "sacred cubit:") = 9131" .05. Hence this sloping line from the fundamental socket to the one next to it, expresses the required cosmic ratio in pure and simple figures. As it is a sloping line its mathematical significance is that of ratio, a fact which should not be lost sight of in this discussion.

Again, the sloping line being 9131".05, the horizontal one from the south-east socket to the arris line produced through the north-east socket—i. e., the base side of the fundamental square—is exactly 9139".87 + inches, or is the functional value demanded by pyramid students. and thus again proved by Mr. Petrie's meas-

Against the possibility of such a coincidence President Barnard claims, in the closing paragraph of his argument, that the chances are more than "some millions of infinities to one." Yet here it is President Barnard, along-side of the true sun But this by no means follows when we distance, linked to the true solar parallax, and linked to each, in a cosmic monument, by the actual and modern π value, which was unknown and unused by the ancients. The question therefore for the candid and unbiassed man to answer, is, whether he will stultify himself at the mandate of such investigators as have yet arrayed themselves against the cosmic theory, or admit the monument to be a wonder past the ken of human intellect.

While I am willing to admit that there is much mistaken enthusiasm displayed and admit the overruling guidance of a by pyramid students in their engrossing study, it is nevertheless a fact that the study of this monument is opening up the whole topic of Metrology in a way that sets it before the world as the veritable science of sciences. Its students now include some of the most earnest men of both Church and State, and their investigations have long since raised the "Solution of the Pyramid Problem" far above the discussion of mere coincidence.

Mathematically speaking, there are no such things as "coincidences." In this rigid science "what is must be," and the deeper we examine the Great Pyramid the more our conviction grows that it is a consummate exponent of universal science, or Metrology.

it is "indeed physically possible, that two," and we might add that several,

sults," still it would "exceed all the bounds of credibility, and exceed all the powers of credulity" if they should prove so. But they do prove so, hence as facts they are credible, hence too they being facts so physically beyond the range of accident, our credulity must cease, and in its place give room to honest conviction of magnificent design and, if it be not possible that such should be of human origin, then we must yield to our convictions hand that wrought far wiser at the Pyramid than the architect himself. If President Barnard and his school decline to accept this alternative, and we challenge them to dispute it, then they must gorge themselves with "several millions of infinities" in the presence of all right-minded men, and in a state of torpor digest their unwholesome and dyspeptic morsel.

To what purpose therefore shall we further discuss phases of this controversy that have long since been worn out. If the opponents of the cosmic theory have any new facts, to relate, which militate against the premises we base our faith upon, we ask them in the interests of science to show them forth. All searchers after truth desire to know them, but Mr. Barnard finally concludes that while until they have, it is far better not to dip their pens in simple ridicule and innuendo, and attempt to wreck a Pyramid, "such entirely independent and inconsist- against whose huge proportions few minds ent schemes of construction should prove can measure themselves with any great to be harmonious in their practical re- advantage.

THE DEFECTS OF STEAM BOILERS AND THEIR REMEDY.

By Mr. A. C. ENGERT.

From "Iron."

tain work.

Steam boilers are used as a medium to and the higher the degree of heat conconvey heat, or the accumulated force tained in the water and steam, the more produced thereby, to an engine for the pressure will the steam exert on the pispurpose of moving machinery to do cer- ton when allowed to enter the cylinder. The heat rises from the It is of the utmost importance to have burning fuel within the boiler furnace, perfect combustion, so that the whole of and penetrates the metal to heat the the heat may enter the water in the water in the boiler to 212° F. so as to boiler. For this purpose various shapes form steam; but before its actual forma- and forms of boilers have been invented, tion 966° F. has to be absorbed. Steam but the Cornish and Lancashire types has no power to move a piston at such a are found the most convenient for genelow temperature, therefore more heat is ral purposes. Now 1 lbs. of good coal is required to produce the necessary force, capable of evaporating 15 lbs. of water,

to thoroughly penetrate the metal. Improvements have, therefore, been introduced, such as Galloway and other cross inch thick, 60 per cent. more coal is reto incrustation. This evil of incrustation, desires to draw attention to the remedy together with unequal expansion and which the chairman of the Manchester contraction, and the corrosion in boilers, Steam Users' Association has recommendof these evils are due to the construction a 50 horse-power boiler, and to frequently of Cornish and Lancashire boilers. For blow off. Besides this, he recommends instance, the ashpit, which is used to the Porter-Clarke process, which consists furnace, allows cold air to enter which water, which throws down all the car-keeps the bottom part of the boiler cool, bonates, and the water is then filtered and stays the circulation of the water and ready to be pumped into the boiler. within. If warm water even be fed into Still, this process does not touch the the boiler a part of the heat is again lost sulphates. from the above cause, and the heat supplied to the bottom of the boiler is also formation of smoke and the loss of unpartly lost, so that the lower part of the consumed gases. In reference to this, boiler is almost entirely useless for the author had the honor, in June 1881, forming steam. Another trouble arising to read a paper before this society "On out of this evil is the unequal expansion the Prevention of Smoke"; he also sent of some of the plates. The top part of a letter to the editor of Iron (which was the boiler being hot and the bottom cool, causes great strain at various seams, as 1883) entitled "The Cause of Smoke," the expansion and contraction are con- of which the public has never been intinually affected by the varied draught formed. A few points therein may, or temperature, often loosening rivets perhaps, be restated here, as some of the and causing leakage, and endangering younger members of the profession may life and property. Another bad feature have thought the subject too unimportant in this description of boiler is that the to be enquired into. The author wrote bottom of the flue and the shell being as follows: "When fresh coals are placed very close together it is hardly possible on the fire in an open fire grate smoke to clean those parts properly. This is of rises directly. The cause of this smoke great importance, as on that particular is not very far to seek, as it will be easily part the most settlement takes place, understood that before the fresh coals the water being there almost station were put upon the fire within the grate,

boilers are subject, incrustation is one of enabled the rising gases at once to comthe principal, because all waters contain bine with the warmed air to produce certain impurities which settle in the combustion, but since the fresh coals are boiler, as the heat cannot dissolve nor placed upon the fire these coals absorb

but these boilers are only capable of drive them off with the steam. These evaporating one-third or at the best one-half of-the quantity of water they should steam is formed, and get baked into a do in proportion to the fuel consumed hard scale on the plates, but mostly on (which is far too small a proportion), ow- the crown of the flues and conical tubes. ing to the flame and heat wave rushing As this scale is a non-conductor of heat, it through the flues too quickly for the heat requires 15 per cent. more coal when the scale is only one-sixteenth of an inch thick; and when it is a quarter of an tubes, in the Cornish and Lancashire quired. It is not only the coal which boilers, which have proved to be very is thereby wasted, but the water is kept advantageous in saving fuel, so long as away from the boiler-plates, which bethey are kept clean. But even with come overheated, and eventually have these improvements the average evapora-tion is not much more than half that tation, various solutions and many other which theory shows it should be owing remedies have been tried. The author are hindrances which ought to be re- ed. This consists in putting 3 lbs. of moved. In the author's opinion several soda ash every day in the feed water of convey air to the burning fuel in the in putting lime water into the feed

Another trouble with boilers is the the glowing coals radiated their heat and Among the general evils to which warmed the air above, and thereby

the heat, and the air above remains cold. stokers profess to do, observes that very The fact is that these volatile rising gases many mechanical stokers are thrown out of cannot combine with the cold air for combustion, still a combination does take place in the following way: The cold air in the act of combination absorbs a part of the warmth of the rising gases which the long run is that the mechanism is they cannot spare, and therefore they troublesome, wasteful and costly. Later (the gases) must condense, so much so on it is stated that "it would be interthat small particles are formed, which esting to know the actual number aggregate, and are called smoke, and that has been fitted to boilers during when collected form soot; but so long as the past five years, and in how many these particles or gases are floating they cases they are still at work." In the cannot burn or produce combustion. Of report of the Manchester Steam Users' course the invisible hydrogen gas rising Association, April 24, 1883, is the folfrom the coals with the smoke would burn easily enough, but it must be first lit before it can burn." The above chanical and hand firing, had been carein furnaces smoke and waste of gases the conclusion arrived at was that, as may be caused by too small a quantity regards economy, the two modes of firing through the furnace, absorbs heat tion. In the paper on the prevention of smoke, only a reasonably fair draught, a reasonamount often to a high percentage) which cal results. go out with the smoke, but also the stokers have been invented, not only to within the furnace.

use after a time, and the old hand-firing again resorted to. It is also remarked that though the machines are pleasing and satisfactory at first, the main result in sentences only refer to open fire grates; fully considered by the association, and of air, so that there is not enough oxy- ing gave practically the same result; as gen to satisfy the rising gases, or there many as fifty-five mechanical stokers had may be too much air, which, whilst pass- been removed from boilers under inspec-To prevent smoke by hand firing, and thereby impoverishes the combustion. nothing out of common was wanted, but read before this society, the author ex- ably fair boiler, regular firing, and the pressed a strong opinion that smoke once admission of a little air above the firebars formed could not be consumed, and gave to secure the combustion of the gases." his reason, and he finds the following in In the report of the Jurors' Committee a work frequently consulted by boiler of the Smoke Abatement Exhibition, it makers: "We see, then, how palpably is stated on page 25, as to mechanical erroneous is the idea that smoke once stokers, that "most of them require ocformed can be consumed in the same casional assistance by hand," thus showfurnace in which it is generated, and how ing that they are still open to further irreconcilable is such a result with the improvement. In the above report it is operation of nature, and it is only the stated, on page 27 (Firebars, fire-bridges, cooling down of carbon which produces furnace-doors, &c.), that "the committee Here then again smoke is at- are of opinion that any assistance by tributed to the cooling down of the gases, which air is introduced with the view to and the author thinks the cause not only complete the combustion either of gasof the loss of a few grains of carbon eous or of solid fuel is objectionable, and and the other invisible gases (which is not likely to lead to the most economi-

These statements of high authorities trouble and unhealthiness produced by support the author's opinion that smoke the smoke cannot be referred to too often. cannot be burned in the same furnace It is, of course, well understood that where it has been formed, and much less cold air must be prevented entering the is any furnace door able to produce comfurnace, and for this purpose mechanical plete combustion of the fuel burning In fact, entire comprevent the formation of smoke, but to bustion is almost beyond the means of Experience, however, has man, in an ordinary furnace. Still, imtaught us otherwise. Referring to the provements have been made by introduc-Manchester Smoke Abatement Exhibi- ing warm air, to combine better with the tion, Engineering of April 28, 1882, rising gases of the burning fuel. But after stating what the various mechanical even this is no easy matter, considering

that 150 cubic feet, or 22 lbs., of air are closes the furnace door. This method required for each pound of coal burnt; and it is a fact that the carbon requires great heat before it can be burnt, and further, that all solid fuel formed into gases and compressed gases while expanding absorb a large quantity of heat before they can burn. On this subject, Engineering, of December 2, 1881, says: "Total combustion means, not merely the rendering the products of combustion invisible, it means the conversion of the carbonic oxide produced into carbonic acid." Another author says: "The carbon burning in the flame has not completed its combustion, and it is only the high temperature of hydrogen burning which will enable the carbon to combine more readily with the oxygen in the air." It is only the clear white flame which will show that combustion is in its proper condition and everything is well heated. To prove that the carbon in the flame is only completing its combustion may be seen by the flame of a gas jet or of a candle, which gives a very white light, as, for instance, the Siemens gas lamp. But if a little air be allowed to blow in from the bottom, then the white light will blaze out in a long dark red flame, and give little light, but plenty of smoke and soot. Again, if a plate be held over a gas or a candle flame, carbon, i. e., soot, will settle on it, and the deposit is increased when the plate is held lower in the flame, in fact the burning of carbon in a flame is only one of the stages of combustion, and when combustion is interrupted or incomplete it produces smoke, which is increased, while the invisible steam formed by the hydrogen will condense and cling to the dust of the carbon. This can be proved by the flame in a furnace; the lowest part of the flame where the carbon has just combined with the oxygen is generally much darker, even when the top is quite white, and thereby gives the greatest heat of some 2000° F., and when the flame is entering the tubes of a marine boiler, the bottom tubes are getting choked with soot, and the top flues, owing to the white flame, remain clean, and produce the heat required for forcing steam. When fresh coals are placed in the fur-

the author thinks entirely wrong, as the heat from the fire underneath drives out the gases from the green coal in such rapid succession, that it is almost impossible for combustion to take place, even if the materials were ready for combustion. Such, however, not being the case, most of these valuable gases escape and are unproductive. If the fire on the dead plate were raked to the front near the door, and the green coal placed on the dead plate between the two fires, the small quantity of air entering the furnace door when shut would be warmed, and would ignite the rising gases from the green coal. At any rate, the first gas rising from the green coal is generally hydrogen, and as this gas has a greater affinity for oxygen than for carbon, it takes the first supply to form invisible steam and producing the greatest amount of heat whilst burning, thereby preparing all the other gases for proper combustion. To carry out this plan, the dead plate might be made a little larger so as to receive more coal at longer intervals, but the carbon gas at first very seldom combines with more than eight volumes of oxygen, forming carbonic oxide, as the carbon gases have to be formed from the solid carbon, and only afterwards while burning combine with eight more volumes of oxygen to form acid. Of course, if the draught is slow, which is always better for proper combustion, and if there be more carbon gas within the flame, then another six volumes of carbon gas is absorbed, and oxide is formed again. This then would be something like proper combustion, and would produce the heat required. But where is the quantity of warmed air to come from in the Cornish and Lancashire boilers? As the jurors state, in their opinion "air ought not to be allowed to enter above the firebars." Some very elaborate furnaces with hot air chambers have been built, but they are so expensive, and occupy so much space, that they are rarely employed. The atmosphere passing through the firebars, and incandescent fire above, is not at all times sufficient for complete combustion, especially when the draught is weak; and nace, the stoker generally leaves a small as it has been shown that burning carquantity of fire on the dead plate upon | bon is taken up by another eight volumes which he places his green coal, and then of oxygen, it is almost necessary to apply combustion of all the gases is to take place. The densest smoke is formed when stoking is commenced, or the partly burned coals in front are pushed backwards on the firebars. The coals now disturbed having been warmed and their pores opened, the previously confined gases rise in a mass, but meeting the cold air entering partly from the open fire-door and partly through the firebars, the gases condense and form smoke. Tosave this great loss of gases, and to prevent the formation of smoke, the damper ought to be nearly closed before the furnace doors are opened. If this plan is not adhered to, the owner of the boiler will not only lose all the gases as stated, but in addition some 8 lbs. to 10 lbs. of coals, to make good the cold which has entered the furnace and flues by the door.

Priming is another trouble common to boilers in general, and although a very important matter, the author has been unable to find any reference to this subject even in the most important works on boilers. He, however, found in a paper read before this society by Mr. Wm. Major, on April 9, 1877, the following: "It is certainly humiliating for the prosubdue an evil so generally experienced steam. the case, as proved by the Serapis." Further on it is stated that tallow and other remedies have been tried with various results, some doing harm to the boiler plates. It is, however, stated that petroleum, mixed with the feed water according to Mr. Major's invention, proved perpetroleum being used per day in a 30 horse-power boiler. Beyond these statements very little is said about the cause and remedies of priming. The author will now give his opinion and experience of priming in boilers. The warming up and starting of an engine in the

warm air above the firebars if the proper and considering that the flues by that time are not very hot, and are not able to form steam, the whole formation of the steam required is thrown on one small plate or space just over the bridge of the Cornish or Lancashire boiler. In fact, this small part of the boiler has produced or formed the whole of the steam and pressure within the boiler, and therefore this part must be very hot, and the water close to it absorbs more heat for expansion to form steam, and is consequently lighter than the water just above it, and possesses greater accumulated heat for the moment than the steam bubbles already formed. The heated water, with the lighter steam bubbles, are therefore thrown up together, when the pressure from above is suddenly removed, and forced into the engine. working of a vertical boiler may serve to make this clearer. The steam formed having to force its way up through a column of water from $1\frac{1}{2}$ to 3 feet deep, of course produces some pressure, and the water on the top being cooler than that at the bottom, the single bubbles of steam are hardly able to force their way up, and a combined effort is required (which may be said to cause a convulsion fession to be obliged to admit that one within the column of water) for the hundred years after the introduction of steam to raise itself, and then the superthe steam engine they are still unable to heated water is thrown up with the This so-called priming in the as priming of steam boilers; yet such is vertical boiler is not seen in the water gauge so long as the water is kept low, say about 3 inches in the glass, but if the water be pumped as high as, say, 5 or 6 inches, then the water thrown up with the steam shows itself in the glass from the top. This, then, proves that the water forced up with steam will by gravfectly successful, as shown by a letter ity fall back in about a space of 3 or 4 from Copenhagen, about one gallon of inches from above the water line, and the steam so cleared will show very little priming. Pure water will, no doubt, prevent priming to a great extent, but where boilers are forced or the water stands too high in the boiler, then the convulsion will be stronger, and a higher space for the steam to clear itself will be required. morning requires a large amount of These facts prove two things—firstly, steam, as considerable condensation that in most instances the heat is applied takes place at first, more especially in on too small a space, and thereby harm is the winter. The great quantity of steam | done to the boiler; and, secondly, that taken from the boiler in so short a period the steam space above the water line is very often reduces the pressure of steam insufficient. These two conditions not within the boiler some 25 to 40 per cent., only destroy or do harm to many boilers

and engines, but cause a loss of fuel and power. The best means for the prevention of priming will be explained later

The author thinks too little attention has been given to the air and gases with acids contained in the feed water by steam users in general, as these acids not only corrode the boiler plates and produce galvanic action with the grease returning to the boiler with the condensed steam, but the gases accumulating in the boiler amount to something more than is generally supposed. All water contains at least 2 to 3 per cent. of absorbed air and gases; such air and gases being continually pumped into the boiler accumu- two flues have one fifth more room for late. It is known that all gases are by water and steam than the two flues of a gravity heavier than steam, the steam be- Lancashire boiler, the top flue having its ing on the top in the boiler is allowed to front bottom plate slanting downwards to pass from thence to the engine, the gases remaining behind, and, as carbonic acid On the front of the boiler a cast-iron box will use about 3,000 gallons of water per perforated baffle plates. 14½ cubic feet of various gases accumulated, and in a week some 80 cubic feet. These gases can only be expelled from the boiler by frequent blowing off; and if this be neglected, the gases and acids the author is of opinion that if an explomore violent on account of the accumulated gases. They increase in volume as 1 in 490 at every degree F., so that at 50 lbs. pressure the accumulated volume of gases will nearly be doubled, and thereby give an after pressure to the steam to blow the boiler to atoms. The Manchester Steam Users'Association and other authorities have expressed the opinion that there must be something beyond

boiler designed by himself, which has undergone some very severe trials. The places. The flame or heat waves in their undergone some very severe trials. The object of the author was principally to vol. xxii., page 309.

do away with the ashpit; to prevent, if possible, incrustation; to extract from the water all gases; to prevent unequal expansion; to produce dry steam, and, by having better combustion, to prevent smoke. To obtain these results, he designed and had manufactured a boiler* in which two flat flues are placed one above the other in a cylindrical shell 16 feet 6 inches long by 7 feet diameter, of which the top flue is 4 feet 8 inches wide by 10 inches high, and the other 4 feet 6 inches wide by 10 inches high, the top one being stayed with 24 and the bottom one with 33 3½-inch vertical tubes screwed into the fire-plates and expanded. These make room for the firebars and furnace. gas is the heaviest gas, it takes the low- is fixed with the bottom open, having est place. Now, a 50 horse-power boiler doors in front with slots and slides and The firebars day; then there would be as much as rest in front on a strong bar within the cast-iron box, and the back end of the firebars rest on the top end of the slanting flue. The front ends of the firebars are turned up to prevent the fire falling out. A sheet-iron curtain hangs accumulate to a very great extent; and down, so that when the doors are opened the fire is not exposed; when sion then took place, it would be much firing is required, the curtain is raised, and the damper is nearly closed automatically, so as to prevent cold air rushing into the furnace and flues. On the back end of the boiler there is a closed tank, 4 feet 8 inches wide, extreme height 4 feet, and 1 foot 10 inches deep. The water is supplied by gravity from a higher cistern, and a 2-inch pipe is carried from the tank through the roof, for the purpose of discharging the air and acids. steam pressure in many explosions. The The firebars sloping towards the front return side and bottom flues of a boiler were designed so that the air should not ought to be rounded off, as all corners merely pass through the firebars, and prevent the proper flow of the air and then rise to the boiler plate, but that the heat waves. A few bricks sticking out burning gases, drawn towards the flue, in the flues from the brick walls will should continually meet and amalgamate throw the heat-wave towards the boiler. with the other gases and meet the warm The author having stated some of the air coming through the slots in the existing faults and their remedies in front doors, so as to produce carbonic Cornish and Lancashire boilers, will now acid close under the boiler-plates, and to explain the improvements made in a evolve the greatest heat at the proper

passage are retarded by the vertical The vertical tubes after one year and atubes, which they embrace, and thereby quarter of work are found to be as plates; the other part of the flame rush- in. goes on at the bottom flue. Passing out at the front, the heat is led to the right side flue, returning under the bottom of the boiler, and passing to the left side towards the damper and shaft. The water does not remain long enough in the tank to be sufficiently boiled to throw down the carbonates and sulphates of lime, and therefore a live steampipe is pipe some 240° to 250° F., which heat will throw down the carbonates and sulsend the acids and air out of the tank. most pure, and at the boiling point, it per lb. of coal. produces no settlement or scale within

never to be employed above the firebars. flue-plate of some 80 square feet below,

spread the heat to the top and bottom clean as if they had only just been put The circulation is so rapid there is ing by will do the same duty by the next no settlement on the bottom of the tube, and so on to the end of the top boiler. On the top flue only there is flue. Here the heat wave is obstructed found a small quantity of sediment, by a water tank for boiling the water which is easily removed by a water hose, contained within it, and the same process and the scum on the sides of the boiler can be easily brushed off. Another advantage is that the bottom of the flues produce almost as much steam as the top, because no stationary steam globules are permitted to accumulate in consequence of the rapid circulation through the vertical tubes, in which no settlement or scale can attach itself. However large the flat flues are made, it is impossible carried from the boiler into the tank, and for them to collapse on account of these enters a large 4-inch pipe, which, with 50 vertical tubes or stays. The total heatlbs. pressure, will produce close to the ing surface is 577.7 square feet, and the grate surface 13 square feet. There are, therefore, 44.4 square feet of heating surphates (which are drawn off below) and face per square foot of grate surface. The author finds, that by a slow combus-The feed-water supply is taken from the tion and a gentle draught, more heat is hottest place over the pipe and is pumped evolved and penetrates the metal, and into the boiler, and as this water is al- that therefore more water is evaporated

There being no ashpit in this boiler, and the boiler being entirely bricked in, The steam supplied to the water tank no unequal expansion can possibly take is then led by a pipe to the front under place. As no cold air is allowed to enter the firebars, and allowed to escape in the furnace, no smoke can arise except small jets for the purpose of warming at the moment the curtain is let down the air under the grate. The steam and the damper raised; but this vapor passing through the incandescent fire is so trifling that it is hardly worth menwill be partly dissolved into its two ele-tioning. A boiler on this principle was ments, oxygen and hydrogen, of which laid down by the author for driving the the oxygen will at first fly to the carbon, machinery at his works in Three Mills and the hydrogen will burn above with Lane, Bromley-by-Bow, in December, fresh oxygen again to invisible steam, 1882, and has been tested by several inwhich, if collected, would produce near-ly a ½ ton weight of water from a ton of coals, if proper combustion had taken With this boiler there is no priming, dry place. The steam jets are principally for steam being produced (as stated in *Engi*the purpose of obviating the necessity of neering for September 14, 1883), tests a very strong draught. The damper behaving proved it to be thoroughly drying half closed to prevent the heat from Mr. D. K. Clark, in his report, states: "I entering the chimney, the quantity of tested the steam produced each day for steam supplied under the front bars is dryness; it proved to be dry and free very small, for if a large supply of steam from priming water." The explanation was used it would become superheated of the dryness of the steam is very simple, by the burning fuel, and rise by its grav- and is due to the large flat surface of ity close under the boiler plate, thereby water in the boiler, of about some 112 preventing the heat from penetrating the square feet area, which for the most part metal, and proving that steam ought is only 3 inches deep, and having a heated and twenty-four vertical tubes, which with a volcanic action continually send up the steam formed within them, and that from below, caused by widely-distributed heat waves. Then there is such a rapid circulation that no pressure arises from a volume of water, and there is no force or convulsion present to form steam bubbles. With shallow water and welldistributed heat, priming is therefore

prevented.

Thus the principal defects of boilers have been remedied by this new design. There is very little waste or ashes, no clinkers in general, and only a few cinders, which may be used again. stoking is very simple, as the coals are placed almost in front, the bars are short, and slanting to the front. In Iron of October 5, 1883, it is stated by the editor that this boiler has realized the highest efficiency on record, and that it marks a new phase in boiler construction. In the Times of September 17, 1883, the editor favored the invention with a similar opin-Mr. W. H. Maw and his staff made five tests during nearly six months, of which the author here gives the last. An elaborate report of the same was published in Engineering of September 14, 1883, in which it was stated that the boil- The report is dated January 18, 1884.

er embodies a number of novel features, and produces rapid circulation through the vertical tubes, the effect of the curtain being very marked, and that as a rule there was no trace of smoke.

RESULTS OF EVAPORATION TESTS, Aug. 31, 1883.

Duration 8. A. M. till 5 P. M., 9 hours.

Steam pressure, maximum, 50 lbs. per square

Steam pressure, minimum, 39.5 per square inch. Steam, mean, 45.5 per square inch. Coal, total quantity burned, 1,015 lbs

Coal, quantity burned per hour, 112.8 lbs. Coal, quantity burned per square foot of grate

(short bars), 8.68 lbs.

Ashes weighed, containing fragments of coal and clinker for which no allowance was made, 39 lbs.

Area of grate, 13 square feet.

Water, total quantity evaporated, 1,150 gallons. Water evaporated per hour, 127.7 gallons.

Water evaporated per square foot of heating surface, 2.2 lbs.

Water evaporated per lb. of coal, 11.3 lbs. Temperature of feed water, mean, 81.6° F. Temperature of gases measured in fluc between

damper and chimney, 290° F.

Draught, mean, in inches of water, $\frac{5}{16}$ inch.

The National Smoke Abatement Association had two tests made by their engineer, Mr. D. K. Clark, who gave a minute report of the boiler in question, and from which the following figures are taken.

RESULT OF EVAPORATIVE PERFORMANCE AND EFFICIENCY OF THE ENGERT STEAM BOILER, LONDON, 1883.

Number of Trial.	1.	2.	
Date of trial. Temperature of boiler-house, average. Barometer Average. Duration of trial. Average effective pressure per square inch in the boiler. Net quantity of coal consumed at trial. Net quantity of coal consumed per hour. Net quantity of coal consumed per hour per sq. ft. of firegrate. Ash (no clinker) residue. Ash residue per cent. of net coal consumed. Average temperature of water supplied for consumption. Quantity of water supplied for consumption. Quantity of water per hour. Quantity of water per hour per square foot of grate. Quantity of water per pound of coal consumed. Quantity of water per pound from and at 212° F. Quantity of water per pound of combustible. Quantity of water per pound of combustible from and at 212° F.	133 lbs. 10.23 lbs. 74 lbs. 7 per cent. 73,5° F. 202.5 cubic feet.	Dec. 21, 1883. 57.3° F. 29.90 inches. 8 hours. 36.6 lbs. 1,568 lbs. 196 lbs. 15.10 lbs. 84 lbs. 5.36 per cent. 70° F. 236 cubic feet. 29.5 cubic feet. 9.37 lbs. 10.96 lbs. 9.90 lbs. 11.58 lbs.	

the following remarks:—"On the first by increasing the draught, in order to day the boiler was worked at the usual test still further the capabilities of the pace to supply steam for daily require-system. In point of efficiency the results Vol. XXXI.—No. 3—17

Mr. Clark concludes his report with ments; on the second day it was forced

smoke can be entirely suppressed. Shortly scale or deposit. after the two days' tests were completed, the boiler was opened in my presence, entirely free from scale, and was otherwise in good order. I may add, in conclusion, that in my opinion Mr. Engert has produced a steam boiler of much neering."

engineer of the London Mutual Boiler upon it.

compare favorably for the Engert boiler. Insurance Company, the last inspection On the system of firing for this boiler, having been made on November 9, 1883. which does not demand more than an Upon each occasion the inspector reportordinary degree of care in management, ed the boiler to be clean and free from

In conclusion, the author would submit and I found on inspection that it was that the defects of steam boilers and the evils of incrustation, priming, and bad circulation are largely, if not wholly, due to faulty construction, and that he has succeeded in remedying these defects. merit, and that he has made a new and He submits this with confidence, not so effective departure in steam boiler engi- much upon his (wn authority and experience as upon those of independent engi-The interior of the boiler has also been neers who have investigated the working inspected upon two occasions by the of his boiler, and have reported favorably

THE FOUNDATIONS OF THE NEW CAPITOL AT ALBANY.

BY WILLIAM JARVIS MCALPINE, M. Inst. C. E.

From Selected Papers of the Institution of Civil Engineers.

information to establish a rule for determining the load which may be safely imposed by a structure upon earth of a specific character and condition. The degrees of consistency and compactness in different kinds of earth and their mixtures, and, above all, the extent of moisture therein, so affect the supporting power as to discourage any attempt at a formula for practical use. The nearly upon the previous experience of the locality, or upon observations of structures supported on similar earths in like conditions; in fact, to guess at, what the Author believes may, in most cases, be determined with considerable precision, and avoid on the one hand the unnecessarily costly foundations which are so frequently observed, and, on the other hand, those inappropriate and insufficient foundations which cause the destruction of the superstructure.

remarkable extent. It was also found been fully accomplished; and when the

THE Author has not met with sufficient, that the earth, to a great depth under many portions of the foundations, received and parted with a considerable amount of moisture with the changing seasons. The circumstances of the case did not allow the use of piles or inverted arches; it was, therefore, necessary to spread the base of the walls over such an area as would afford the requisite sustaining power, and also to protect the clay and sand from any excess or deprivation of universal rule seems to be, to depend its natural degree of moisture, so as at all times to derive from it the same degree of support. The importance of the work warranted the expense of experiments to determine the questions above referred to. In the absence of any similar or equally extensive experiments, the author is induced to submit the present ones, in the hope that an explanation of the methods adopted, and the results attained, will prove serviceable.

The structure, though a single building, may be considered as a collection of He was requested ten years ago, to a dozen large ones, with great differences devise plans for the foundations of a large of elevations, and weights upon the lower and costly State building, which had to walls, and yet so bonded together as to rest upon soil apparently equable and require that the pressure of each of the stable, but which proved, on careful exparts should be the same per square foot amination, to lack these qualities to a on the earth beneath. This object has

extent of 200,000 American tons, the au- blue clay. thor believes that it will not compress three-fourths of an inch, and exactly the cent. of moisture. same under every part thereof. building measures nearly 300 feet by 400 feet on plan, and has three main stories and a basement. The lower walls are 110 feet high, but those of the corner towers, pavilions, and main tower, are of

much greater height.

The ground covered by the structure sloped eastward at the rate of 1 in 25. The pit was excavated to a depth of 5 feet below the natural surface at the south-east corner, and 25 feet at the north-west corner. The excavation, together with the borings which were made in the bottom of the pit, fully exhibited The lower the character of the earth. strata (termed in the locality "blue clay," and "Albany clay") are more than 100 feet in thickness, resting upon the Hudson River Argillite (a clay state), the two forming the banks of the river for 30 miles of its course. The "blue clay" contains from 60 to 90 per cent. of alumina, the remainder is fine silicious sand. It also contains many nodules of clay, the form of rings and discs about an inch in diameter. Overlying the blue clay was a mass of earth from 1 foot to 35 feet deep, composed of the same clay mixed with sand of different degrees of fineness, in proportions varying to such an extent as, when saturated, to render it in some places, a semi-fluid, while in others it was nearly pure sand, and very porous. This material occurred in veins and strata, large and small, above and below the level fixed for the foundation. One of the largest of these veins of viscid earth passed diagonally across the foundation, and at a depth of 6 to 20 feet below the bottom of the pit. It was 200 feet long, and from 5 to 25 feet wide.* Other veins and strata of less size, were found extending across the bottom, and sometimes terminating in pockets in the blue clay. Borings, from 10 to 30 feet deep, were made in several places below the bottom of the pit, which showed the substratum to be blue clay; and a well which had been sunk close by,

structure is loaded to the maximum to a depth of 100 feet, was entirely in the

The earth in its natural condition at the earth upon which it rests more than midsummer contained from 27 to 43 per When the samples The were thoroughly dried and pulverized and again fully saturated (without dripping), they absorbed from 39 to 46 per cent. of water. The blue clay ordinarily held about 40 per cent., and when dried, again absorbed about 43 per cent. It was, therefore, as a rule, completely saturated in its natural state. It was upon this kind of earth that the subsequent experiments of the supporting power of the clay were made. The pure clay, obtained by separating it from the sand, weighed 116 lbs., and the sand so separated 80 lbs., per cubic foot; but, when they were again mixed in different proportions the weight of the mixture was less than the proportionate means between them. Earth taken from the same places as the samples, varied from 81.5 to 101.4 lbs. per cubic foot, depending upon the proportions of the clay and sand; and these weights show, to some extent, the relative supporting power of the earth at the places from which the samples were taken.

It was originally intended to support highly charged with carbonate of lime in the structure upon wooden piles, of which a considerable number had been procured before the author was entrusted with the direction of the work. Many comparatively large buildings in Albany have been supported upon wooden piles driven into the blue clay or upon thick planks laid under the walls. In a few cases the wood used for this purpose has been found in tolerable preservation* half a century after it had been buried in the blue clay; but, generally, such timber was much decayed at the end of a quarter of a century; and several heavy buildings, after having stood firm for twenty years, began to settle, and the walls to crack, in consequence of the decay of the wooden supports and the unequal settlements therefrom. It appears that when the clay had been kept constantly moist, the wood did not materially decay in half a century; but, wherever the moisture was drawn off, the wood did not last more than twelve years. In this case, even if

^{*} This vein was dug out, and replaced with clay and sand artificially mixed, moistened, and slightly rammed in layers, so as to render it as similar to the adjacent natural material as possible.

^{*} In digging the trenches for the street pipes of the new waterworks at Albany, the author had occasion to remove many of the old pine water-pipe logs, of which only the sap wood was decayed. They had been buried in the blue clay for more than half a century.

a wooden foundation could have been ar- Passing around the exterior walls of one also have eventually decayed.

The use of sand and concrete piles, made by boring or driving holes into the clay and filling them with these materials, was also considered. For reasons which will subsequently appear, inverted arches could only be used under a part of the structure,* and it was deemed advisable to have but one system of support. The author, therefore, finally determined upon the plan which has been executed.

In most buildings, except where spires or towers are introduced, the weight is nearly equably imposed upon the several lbs. per cubic foot. The floors, including foundation walls; but in the Capitol the the iron box girders, cross beams, brick main and pavilion towers are much higher and heavier than the adjacent walls. The extremely heavy fire-proof floors, loaded crowds of people upon the floors is taken as they will be frequently with dense crowds of people, books, &c., must necessarily carry their load to two only of the four surrounding walls, and, with some of the roofs acting in the same manner, will produce very unequal pressures upon the foundations.

The weight of the whole building and its contents when in use will be 200,000 American tons. The area of the base of the exterior and court walls, and the rear walls opposite, is about 24,000 square feet, and sustains an average of $6\frac{1}{2}$ tons per square foot on the basement walls. The main tower, which weighs 30,000 tons, has an area of 2,508 square feet, equal to 12 tons per square foot upon its foundation walls. The weight on the foundation under the exterior walls of the corner towers is 47 tons per lineal foot; on the interior walls of the same towers, it is only 39 tons; and on the adjacent division walls, 23½ tons. Still greater differences in the weight on adjacent walls occur in other parts of the building, especially at the main tower, where the weight is 134 tons per lineal foot, and on the adjacent walls but 47 tons and 39 tons.

ranged so as to be kept constantly wet, it quarter of the structure (the remainder would have ultimately decayed; and its being a repetition of the same sized walls), use was, therefore, inadmissable. Cast- the weights to be supported per lineal iron piles of white iron could be relied foot are successively as follows: commencupon for a century or more, but would ing at the main tower, 134 tons (which may possibly be increased); the adjacent walls are 47 tons per lineal foot for 60 feet; next, $44\frac{1}{2}$ tons for 60 feet; next, 47 tons for 120 feet (turning the corner tower); next 44½ tons for 60 feet; next, 67 tons for 18 feet; and next, 50 tons for 52 feet to the center of the south or north front. On the rear of each of these walls, the interior wall is loaded with 39 tons, and the division walls with $8\frac{1}{2}$ to $23\frac{1}{2}$ tons per lineal foot.

> The exterior walls of cut granite facing, backed with rubble and brick, average 150 arches and covering, average 24 lbs. per square foot. The possible weight of at 100 lbs. per square foot; the snow upon the roofs, at 2 feet depth, is 12½ lbs.; and the effect of the strongest winds, which may at times be deflected perpendicularly against some of the roofs, is taken at 15 lbs. per square foot. The calculated weight which may come upon each of the walls is as follows: on the corner towers and front foundation walls. 47 tons per lineal foot; on the main east and west front, 50 tons; on the curtains, $44\frac{1}{2}$ tons; on the ventilating tower, 67 tons; on the division walls, extending upwards through four stories, $23\frac{1}{2}$ tons; on the partition walls of two stories, 13\frac{1}{2} tons, and of those which extend one story high, $8\frac{1}{2}$ tons, per lineal foot. The main tower is designed to be of stone, except the portion immediately below the dome, which, from being so high from view, was proposed to be made of iron. If it should be of stone to the dome, that change, together with some others, would increase its weight to 36,000 tons, equal to 14.4 tons per square foot at the base. Its footing stones were spread to 110 feet square, and the concrete to 125 feet square, and 5 feet thickness. The weight on the clay, with 30,000 tons, is 1.92 ton

THE EXPERIMENTS. For the purpose of ascertaining the

per square foot; and with 36,000 tons, it would be 9.3 tons; but it was arranged for an underpinning, if necessary.

^{*}It was necessary to arrange to carry two-thirds of the weight upon the exterior, rear, and court walls, which are separated 120 feet on two of the fronts, and only 90 feet on the other two. Inverted arches span-ning three very unequal spaces would have imposed unequal loads upon the clay beneath, and their use would have defeated the design of distributing exactly the same weight upon every part of the clay beneath the structure.

sustaining power of the blue clay in its natural condition, two sets of experiments were made; in the first by pressure upon a square foot, and in the second upon a Small stakes were driven into the ground, in radial lines from the center of the hole, depth under the foot of the machine, or level; and by means of a straight-edge which had then occurred.

any change in the surface of the ground adjacent to the hole could readily be detected and measured.

Table I. shows a continued settlement square yard, of the surface. The machine of the clay under the foot of the machine used was a mast of timber 12 inches as the loads were added, but no change square, held perpendicularly by guys, in the surface of the adjacent ground with a cross frame for the weights. A was observed until an hour after a weight hole was dug, 3 feet deep, in the bottom of 11,844 lbs. had been applied, when an of the blue clay foundation, 18 inches uplift of the surrounding earth was square at the top, and 14 inches at the noted, in the form of a ring with an irbottom. The foot of the machine was regular rounded surface, the contents of placed in this hole, and weights from which, above the previous surface, meas-2,754 lbs. to 23,784 lbs. were applied. ured 0.09 cubic foot, which is equivalent and the tops carefully driven to the same equal to one-fifth of the whole settlement

TABLE I.

-ton do Day. Hour		Dura-	Weights.		Settle	ement.	
,			Each.	Total.	Each.	Total.	
Mon. Tues. "" "" "" "" "" "" "" "" ""	5 P. M. 9 A. M. 9 '' 10 '' 113 '' 113 '' 1 1½ '' 1 1½ '' 2 '' 2 '' 2 '' 3 '' 4 ½ '' 5 A. M. 8 ''	$\begin{array}{c} \hline \text{Hours} \\ \hline -1 \\ \hline 1 \\ \hline -1 \\ \hline 1 \\ \hline -2 $	lbs. 2,754 2,820 6,260 3,250 2,890 2,980 2,980	lbs. 2,754 2,754 5,574 11,834 15,084 20,954 23,784	Inches. 0.288 0.612	Inches. 0.288 0.900 1.428 6.180 9.768 11.496 11.556 14.844 18.972 24.156 26.216 27.516 30.600 31.200 31.200	The weight of the machine.* First stone added. Second and third stones added. Uplift noted. Fourth stone added. Fifth stone. Immediate set- tlement. Sixth stone added. Uplift noted. Seventh stone added. Uplift noted. No settlement after 5 A. M.
	Tues	Mon. 5 P. M. Tues. 9 A. M. 9 " 10 " 113 " 113 " 114 " 1 1 1 " 1 1 1 " 1 1 1 " 1 1 1 " 1 1 2 " 1 2 " 1 2 " 1 2 " 1 3 " 1 4 1 " 1 1 1 " 1 1 1 " 1 1 1 1 " 1 1 1 1 1	Day. Hour. tion. Hours Hours Hours Hours Solution Hours Hours Solution Hours Ho	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$

Observations 12 and 13 are not reliable. * The first settlement, noted in observation 1, was due to the weight of the machine, and was not a compression, but only a leveling of the rough inequalities of the clay. The subsequent observation 2, of 0.612 inch, is the compression due to 2,754 lbs. This settlement occurred before 5 A. M.

wardly to an average of 4 feet from the chine. center of the hole. This uplifted earth measured 0.606 cubic foot, which is rounding the machine could have taken

When the weight had reached 20,954 equivalent to a displacement of 7.272 lbs., and had rested for half an hour inches. When a weight of 23,784 lbs. upon the clay, a further protrusion was had been applied, and had rested three The form of the ring was the hours on the clay the ring in the highsame as before, but with more irregulest part averaged 0.5 inch high, in the larity of surface. The highest part of same general form and extent as before the protrusion was from 12 to 15 inches noted. The amount of earth thus raised from the edge of the pit, where it aver- was 1.01 cubic foot, equivalent to a disaged 0.3 inch high, and sloped off out-placement of 12.12 inches under the ma-

Before the lifting of the earth sur-

place, the materials first displaced from under the machine were doubtless forced among the particles of the earth adjacent to the whole, and compressed that earth to some extent; and this operation was continued until the adjacent earth had become so compacted as to cause the lifts noted in the table. The author is of opinion that the compression of the larity in the settlement as the load was earth below the bottom of the machine continued without any considerable displacement until after a load of 4,000 lbs. or 5,000 lbs. had been applied, and that then the displaced earth found space in the adjoining earth until the load reached 7,000 or 8,000 lbs., when the uplift became visible at the surface of the ground; but that meanwhile the earth directly under the machine was continually more and more compressed in some proportion to the weight added. The small area pressed upon facilitated the escape of the material into the adjacent earth, which weighed only 300 or 400 lbs. per thor derived from the Tables the opinion square foot. If the pit had been deeper, been less displacement.

made with the same machine, to the per square foot.

bottom of which was framed a strong base, 3 feet square. The pit was sunk 2 feet deep into similar earth, and was 38 inches square both at the top and at the bottom. The stones were put on at intervals of an hour. There was no uplifting of the surrounding earth.

Table II. shows the remarkable reguincreased, and a constant diminution of the increment as the earth became more At the 6th observation the compacted. weight per square foot corresponded nearly with the 2d in Table I., and the settlement was almost the same. The base was nine times as large, so that the proportion of escapement of the earth from beneath must at this time have been It is probable, however, very small. that if the weights per square foot had been increased so as to equal those in Table I., a similar uplift would have occurred, though of less extent. The authat the extreme supporting power of or the piston larger, there would have this earth was less than 6 tons per square foot, and that the load which might be The second set of experiments was safely imposed upon the clay was 2 tons

TABLE II.

Observation.	Weight.			Settlement.		
	Each.	Total.	Per sq foot.	Each.	Total.	
	lbs.	lbs.	lbs.	Inch.	Inch.	
Machine Placed	3,228	3,228	359	_		No settlement that could be measured
1st stone added	2,380	5,608	623	0.050	0.050	
2d " "	3,300	8,908	990	0.150	0.200	Estimated.
3d & 4th stone added.	6,960	15,868	1,763	0.166	0.366	
5th " "		18,698	2,078	0.134	0.500	**
6th " "	3,250		2,439	0.124	0.624	
7th " "		26,368	2,929	0.096	0.720	4.
8th " "		27,558		0.080	0.800	
9th " "			3,320	0.025	0.825	

The notations of the settlement were generally made about an hour after the weight had been applied.

foundation, not only to exclude an excess of water, which might reach it through dental break in the concrete floors within

For the purpose of maintaining the puddle wall was carried up to the level clay beneath the structure in the same of the terrace which surrounds the buildcondition of moisture, a deep puddle ing, yet water might find its way along wall was extended entirely around the the face and down the outside of the the veins and films of sand with consid- and surcharge the clay below. To preerable hydrostatic head, but also to prevent this, there was spread on the tcp of vent the egress of the natural moisture the clay, over the whole area enclosed, a through similar veins. Although the depth of 6 inches of coarse screened

under the great weight of the building tively heavy towers and spires, is to any excess of water in the clay beneath will be forced into this pervious gravel, and flow off through it to the drains which encircle and traverse the foundations. The necessity for these provisions will be apparent when it is considered that many of the veins of sand extend to the surface of grounds of much greater elevation than the foundations, and that from 5 feet to 7 feet thick, where they street sewers and water pipes, while the upon them pressures of from 6 to 9 tons same or other porous veins extend be-per square foot, which had to be reduced neath the surface to grounds which are to 2 tons per square foot on the clay. much lower. Through these sources the This was accomplished by projecting each clay under some portions of the structure of the footing courses beyond those immight be charged with water, while that mediately above them. under an adjacent wall might, at the commence with a load of 2 tons per same time, be drained of much of its nat-square foot upon the clay, 3 tons upon ural moisture, and thus entirely destroy the top of the concrete, and generally 4, the design of a foundation which should 5, 6, or 7 tons upon each succeeding everywhere have an equal sustaining course of stone. The weight on each power. It is not an absolute settlement lineal foot of the top of the foundation which is to be apprehended, but a greater walls, divided by the above pressures, yielding in one place than in another.

gravel, the effect of which will be that have occasion to erect high and comparagroove the lower part into the adjacent walls, so as to allow the heavier ones to slide in these grooves, without breaking the bonding stones. In the present case the demands of the architect forbad the use of grooving, and hence the necessity for the above provisions.

The main walls of the building are they communicate with imperfectly built rest upon the foundation walls, and bring The rule was to gives the exact width of each course of A common practice of builders who the footing stones, as shown in Table III.

TABLE III.

	Load per Lineal Foot.								
Parts of the Building.		Con-		Main Walls.					
		01000	1st.	2d.	3d.	4th.	5th.		
Corner towers, front " rear Curtains, front Central fronts Partitions, 4 stories " 2 " " 1 "	Tons. 47 39 $44\frac{1}{2}$ 50 $23\frac{1}{2}$ $13\frac{1}{2}$ $8\frac{1}{2}$	Ft. Ins. 23 6 19 6 22 3 25 0 11 9 6 9 4 3	Ft. Ins. 15 8 13 0 14 8 16 8 7 10 4 6 2 5	Ft. Ins. 11 9 9 9 11 1 12 6 5 11 3 5 2 2	Ft. Ins. 9 4 7 10 8 11 10 0 4 9 3 0 2 0	Ft. Ins. 7 10 6 6 6 7 5 8 4 3 11	Ft. Ins. 7 4 5 6 6 5 7 2 3 5 —	Ft. Ins. 7 0 5 0 6 5 6 5 8 0 3 0 2 0	

strength of the stone used was main- end. tained throughout the foundations.

these projections could be made without beds of the limestone and granite were

The large quantity of stone required danger of breakage of the projecting in a short time-50,000 tons in four part of the stone. The pressure in this months—compelled a resort to a great case tending to break the stone is that many quarries, which furnished stones of due to the weight on the wall above it, different thicknesses, and made it neces-divided by the width of the wall and sary to modify the above exact arrange multiplied by the area of the projection, ment; but the principle of the distribu- and to treat that result as a load distion of the load according to the vertical tributed on a beam supported at one

To distribute the weight upon the It was necessary to consider how far footing stone courses with certainty, the the weight of each of the upper courses were all headers from 4½ to 7 feet in should be carried out to the extremity of length. The longitudinal bonding was the next course below. The vertical made by the interior stone, and in the joints were only required to be quarry upper courses, where the projections joints, not exceeding 1 inch wide. For certainty and convenience of laying the stretchers of the front stone, as well as masonry, the foundation stones were all the interior. The result of this bonding required to be rectangular blocks, of from 18 to 24 inches in thickness, the breadth equalize its pressure upon the clay. to be at least one and a-half time the thickness, and the length two and a-half much greater than that of the other times the thickness. The average size of walls, and the earth below it so much inall the stones was 31 cubic feet, equal to ferior, that the foundation was placed 7 $2\frac{1}{2}$ tons, and many of them were from 5 feet deeper than elsewhere. With this to 8 tons weight. In the foundations of exception, all the walls were commenced the main tower the average weight of the at the same level. The spaces between granite blocks was four tons, and of the projecting blocks 7 tons. The footing and under the arches of the central court, courses were spread out equidistant from were covered with a layer of concrete, the lines of the center of gravity of the made of screened gravel and hydraulic imposed weight above. The exterior cement, 1 foot to 2 feet thick.

dressed to close parallel joints, so that stones of the three lower footing courses

The weight of the main tower was so

THE COMBUSTION OF FUEL IN FURNACES OF STEAM BOIL-ERS BY NATURAL DRAUGHT AND BY SUPPLY OF AIR UNDER PRESSURE.

BY MR. JAMES HOWDEN.

From "Iron."

ous use of steam in the engine, and not this evaporative duty is reached.

The various improvements in the 1846, an evaporation was recorded per steam-engine which have led, during the last twenty or thirty years to the great reduction in the ratio of fuel consumed to power obtained, have hitherto been lb. of coal is probably not more than 0.6 almost exclusively confined to the motor, and scarcely, if at all, connected with the generator; the reduced consumption average of about 17 knots across the Athaving been effected by the more judicilantic, it is probable that barely half of by its more economical evaporation in the boiler. Putting aside the merely constructional improvements arising from greater experience, better material and but to the different conditions and neappliances, steam boilers for land and cessities imposed by great industrial marine purposes are practically the same as they were when the average consumpthe high economy of the Cornish boiler tion of coal per horse-power developed was obtained are incompatible with main the engine was about three times rine requirements. They would also, as a that of the present day. It may even rule, be impracticable or unprofitable if be said that we have retrograded rather applied to land boilers, especially in popthan advanced, as forty years ago a ulous districts. Time and working space higher evaporative economy was preva- are every day growing more valuable. A lent in Cornwall than is found there or maximum of power in a minimum of anywhere else now. In that district, in space is being more and more sought for.

This demand is diametrically opposed to the essential conditions by which the high Cornish economy was obtained. The rate of combustion was from 3 to 4 fect, because the velocity given to the air lbs. of coal per hour per square foot of supply, even with the sharpest draught, grate, accomplished by careful restriction is insufficient to cause it to penetrate of the air admission to the furnaces. The proportion of heating surface to water evaporated was from six to seven times that further, because a very considerable porof the average in marine boilers. A tion of the heat of combustion is required comparatively low temperature in the to rarefy the air in the chimney to mainhigh chimney gave an adequate draught tain the draught, this expenditure infor the slow combustion, and permitted creasing with the rate of combustion. the heating of the feed water by the Unless, therefore, a much greater supply waste gases after leaving the boiler. Add to these precautions the most thorough protection of the whole boiler from loss of heat by radiation, and we have the conditions by which the high evaporative economy was effected in Cornwall the furnace, part only of the oxygen en-

forty years ago.

Though the necessities of our day render this cumbrous and slow system unsuitable for our steam supply, yet it must be acknowledged that the fact of the higher evaporative power now required from boilers being obtained only Smoke is also formed in large quantities, with a great sacrifice of evaporative economy is inconsistent with the general advance in engineering science, and contrasts unfavorably with the marked economical improvements in the engine or this anomaly is not incapable of being the more complete combustion of the removed, and that even a much higher fuel, an increased admission of air is be had from boilers, along with a higher air—which must always be largely beevaporative economy than is found in youd the quantity required for perfect present practice, that, in short, an approach may be made to the unequaled reduces the temperature of the furnace, economy of the Cornish slow combustion system with an evaporative power, it may power, and, what is still more wasteful, be ten times greater. Experience has robs and carries off to the chimney a hitherto shown generally that, with slow large percentage of the total heat of the combustion judiciously carried out, a fuel. high evaporative economy has been effected by natural draught, but as the fect combustion caused by restricting the raised by forced blast to a rate much union of two atoms of oxygen with one higher than is possible by natural of carbon forming carbonic acid, 14,500 is important at this stage to elucidate the tion only one atom of oxygen unites with causes of this unsatisfactory result, I one atom of carbon and carbonic oxide is how the difficulty may be overcome.

Combustion by natural draught in boilers at the rates now prevalent is necessarily more or less wasteful and imperand mix with the fuel over the whole area of a furnace of ordinary dimensions, and of air is admitted to the furnace than is required theoretically for perfect combustion, it is found that, owing to unequal distribution and imperfect mixture of the air with the fuel over the area of ters into union with the combustible gases and carbon of the fuel, the remainder passing to the chimney unassimilated. The unavoidable consequence is that a considerable portion of the carbon leaves the boiler unconsumed as carbonic oxide. and though this objectionable product contains in itself but a small portion of carbon, it is always an indication of imperfect combustion, and of more important constituents of the fuel being wasted. I hope, however, to show that On the other hand, if, in order to secure evaporative power than now prevails may made to the furnace, then the excess of combustion when properly carried out and consequently the ratio of evaporative

The wastefulness arising from imperrate of combustion has increased the air supply as described, may be estimated evaporative economy has steadily fallen. from the following data. When perfect Further, when combustion has been combustion is effected by the chemical draught, the evaporative economy has units of heat are evolved from 1 lb. of decreased in a still higher ratio. As it carbon, but when from imperfect combuswill endeavor to do so before describing formed, only 4,400 units of available heat are evolved from one lb. of carbon. The

tion can therefore be calculated by ascertaining the proportion of carbonic acid to carbonic oxide in the waste gases, noting also the quantity of air passing away with its oxygen unassimilated. The wastefulness arising from admitting excess of air in order to obtain more complete combustion and reduction of smoke, is estimated by ascertaining the quantity of air admitted in excess. About 11 tons of air attending the combustion of coal by natare required for the perfect combustion of one ton of ordinary coal, if no portion of the air is wasted. Double this quantity, or even a larger proportion is frequently supplied. If double the quantity be assumed, this 11 tons of superfluous air must be heated from the combustion of the one ton of coal, and not only greatly reduces the temperature of the however, have not hitherto been successfurnace, and its evaporative power, but ful, and, therefore, except in locomotives in leaving the boiler at a temperature, it and torpedo boats, supply of air by naturmay be 600° or more, higher than it entered the furnace, it thus carries off a large percentage of the heat of the fuel. The loss stated in figures caused by this 11 tons of superfluous air leaving the boiler at 600° above the entering temperature is $11 \times 2240 \times 0.246$ (the specific heat of the escaping gases) = 6061.4, which \times 600 = 3,638,840, the loss in units of heat, being fully 12½ per cent. of the total heat of combustion of the ton of coal, taking the efficiency of the coal at 12,600 units per lb.

The dilemma, therefore, in which every furnace operator finds himself when working with natural draught, is the choice of admitting either a moderate amount of air to the furnace, and having in consequence an imperfect combustion, with much smoke and considerable waste of fuel, in carbonic oxide passing to the chimney, or of admitting air greatly in excess of what is required for perfect combustion properly effected, and obtaining therefrom a more complete combustion at the cost of a large waste of heat carried off to the chimney by the superfluous air, besides the reduction of the evaporative power of the boiler by the dilution of the furnace temperature. Of these two sources of loss, unfortunately, the greater is generally that arising from the too liberal supply of air, consequently the hotter natural draught. This system of supplyfurnace, with increased steam and much ing air to a furnace is likewise very severe smoke, is preferred by all stokers to the on the fire bars, and has other disadvan-

loss arising from this imperfect combus-less smoke. We thus find, unless it is restricted by the most severe penalties, smoke polluting the atmosphere in every place where steam power is used, hanging over our manufacturing towns like a cloud, and marring the most beautiful rural scenery, as well as our finest rivers and estuaries; a nuisance which apparently owes its toleration to its universality.

The imperfections such as enumerated ural draught, with the limitation of the supply of steam, often further effected by the state of the draught and quality of coal, have led to frequent attempts during the last thirty or forty years to effect combustion in boiler furnaces by air supplied by mechanical means above atmospheric pressure. These repeated attempts, al draught is still in universal use for The causes of failure, steam boilers. though various and often not at first sight apparent, become, nevertheless, obvious when sufficiently investigated. A short description of the most prominent of these attempts to improve combustion by mechanical means may be of some interest. The plan which has probably been most frequently tried is that of forcing air by a fan or other blower into a closed ash pit. This mode of increasing the power of a furnace, though apparently simple, must always be disappointing, for the following reasons:—If the coal on the fire-grate be kept sufficiently thin to permit the oxygen of the air supply to penetrate to the upper layers of the fuel to effect combustion of the inflammable gases, the quantity of air passing through will be too great, and the temperature of the furnace will be unnecessarily reduced, and much loss of fuel occur. If, on the other hand, the coal be laid sufficiently thick to prevent an undue quantity of air from passing through, there will be a lack of air to consume the combustible gases generated by the great heat from the combustion of the lower layers of fuel. Much smoke will in consequence be produced, and also carbonic oxide, so that in this case also less economy will follow than may be realized by cooler furnace with diminished steam and tages which time will not permit reference

It is now exactly twenty-two years since I constructed a boiler to try this mode of effecting combustion by air under pressure. The boiler was erected in the yard in which it was built. It had a short chimney, and the air was supplied to the closed ash pit by an engine and fan. The results of the trials were disappointing, and exactly of the character I have described. They were not, however, altogether valueless, as they clearly showed that forced combustion could not satisfactorily be carried out on this system.

A second method resorted to for increasing combustion in boiler furnaces is that of exhausting the air in the chimney or uptake by a fan, thus reducing the pressure in the flues or tubes and furnaces, and thereby inducing a more rapid current of air through the furnace both below and above the grate-bars. This plan, so far as the supply of air to the furnace is concerned, is in practice more workable than the plan previously described, as the air enters the furnace not only at a greater velocity than is attainable by natural draught, and is thereby capable of being more thoroughly intermingled with the fuel all over the furnace. but being also balanced in pressure above and below the grate-bars, the operations of the furnace become much more easily managed. This mode of creating these advantageous conditions in the furnace is, however, objectionable. The passing of the hot gases of combustion through a working fan of itself a mistake, practically and theoretically. Even if it were possible for the machine to continue in working order under this ordeal for any length of time, the hot gases, if leaving the boiler at no more than 480° above the entering temperature, would be twice the volume of the air which entered the furnace from the stokehold. A fan to exhaust the hot air would, therefore, require to be at least double the capacity of one which would have supplied the same quantity direct from the stokehold to the furnace. This plan, which is one of the earliest tried, is therefore impracticable for large boilers, and has only been occasionally used in boilers of a limited size.

effect on the furnace as the last is that of This is not in itself an economical plan, inducing a current by means of a steam and it has several objectionable features. jet in the funnel. This plan is simple, For marine boilers it is for various requires no working machinery, and is reasons unsuitable. It gives another

within certain limits effective. trates the advantage of mixing the air more thoroughly with the fuel than is possible by natural draught, as by its use a greater evaporative power is obtained, while the consumption of fuel per horsepower of the engine is not more than the rate per horse-power for natural draught, notwithstanding the loss of steam by the jet. The waste of water by this system unfits it for marine boilers working at high pressure, and it is not required in land boilers with high chimneys. It is, however, seen on a grand scale, and in its most legitimate use, in the locomotive boiler, where, instead of merely a small percentage of the steam from the boiler being used for the purpose of inducing a current through the furnace, the whole of the steam generated is used for this The remarkable effect of the purpose. powerful action of the blast pipe is well known. It has increased the power of the boiler at least six-fold that possible by natural draught. What we owe to this power of increased combustion is simply incalculable. It is not too much to say that the amount of traveling and carriage of goods from end to end of the kingdom could not have reached a tithe of its present enormous extent but for this powerful artificial supply of air to the furnace of the locomotive boiler. average consumption of 100 lbs. of coal per square foot per hour is burnt on the fire-grate of an express locomotive, and what should not be overlooked in the consideration of this subject of combustion under air pressure, this astonishing rate of combustion is accomplished with comparative ease and remarkable econo-

A further method of improving combustion, and especially of effecting smoke prevention, which has been frequently tried, is that of increasing the supply of air to the fuel above the grate by currents induced by steam jets. The steam jets penetrate the fuel, carrying with them the air to supply the necessary oxygen to parts of the furnace which would not be sufficiently reached by natural draught. Combustion by this means is improved, A third method producing the same and smoke in large measure prevented.

proof, however, of the advantages, within limits, of an artificial supply of air above atmospheric pressure, as the better combustion it promotes compensates to a considerable extent for its inherent wastefulness.

The most successful plan, in some respects, that has hitherto been applied to marine boilers is that of the air-pressure stokehold or boiler-room, as used in the torpedo-boats—a system so well known to the members of this institution as to render description unnecessary. air enters the furnace above below the fire-bars in the same manner as by natural draught, but at the increased velocity due to the difference of air-pressure in the boiler-room over that of the atmosphere outside. The results obtained in evaporative power approach that of the locomotive boiler. The comparatively small boilers used in these boats, generally of the locomotive type, under the powerful action of the pressure, generate steam sufficient to impart a speed of twenty-five or twenty-six miles an hour to the vessel. The success our own and other governments to apply it to large steamers having a number of boilers with several furnaces in each. It being impracticable to make air-tight a large boiler compartment, and the coal bunkers which must necessarily be in open communication therewith, the plan has been adopted of forming air-tight chambers, or rooms, on the furnace ends of each boiler, or pair of boilers, into which the air is forced by fans working on the deck above. These rooms contain the coals being used by the stokers on duty. Access to the chambers is obtained by doors designed to prevent egress of air. At the meetings of the institution last year a most interesting paper was read by Mr. R. J. Butler, giving much valuable information regarding the application of this system to H. M. steamships Satellite and Conqueror. The results of much larger supplies of steam can be obpossible from natural draught.

are very considerable, even in war vessels, and are more than sufficient to prevent its application to mercantile steamers. The chief defects of the system—and they are serious defects—are its wastefulness and its tendency to injure the boilers. It is a system which may be characterized as one for obtaining an increase of power regardless of expense. After experiencing the impossibility of working a furnace with air under pressure without waste of fuel, unless most carefully studied precautions are adopted, I can state without hesitation that the indiscriminate admission of air in this system must be wasteful of fuel in a very high degree. The effect on the boilers themselves, whenever a furnace door is opened, of the rush at full pressure of a column of cold air, equal to the area of the furnace door, at a velocity from 80 feet to 100 feet per second, must be most injurious. The furnace plates, as well as the tube and other plates of the combustion chamgreat supply of air to the furnace under ber, cannot but suffer severely, while the great volume of cold air lowers the temperature of the whole boiler, and greatly neutralizes the benefit of the rapid comof this system in torpedo-boats has led bustion of fuel. Mr. Butler did not state in his paper the consumption of coal per horse-power developed by the engines when at their highest power, but indicated that when the power was much increased beyond that obtainable by natural draught, the expenditure rose largely out of proportion to the increase of power.

Mr. Butler also stated that in the Satellite, after a few trials, each of several hours' duration only, "a number of the boiler tubes were leaky," and in the Conqueror, after similar trials, that "both seams and tube-plates were leaking," and expresses the opinion in regard to the endurance of the boiler, "that the frequent use of the forced draught would produce a great diminution in the life of those parts subjected to the intense heat." From experience in working boilers on a large scale in a similar manner, that is, with sudden alterations of heating and the trials in these steamers show that cooling, I can fully endorse Mr. Butler's opinion regarding the short life of the tained by this system with less discom- boilers, attributing, however, the injury fort to the stokers than would have been to the boilers not to the intense heat, but to the sudden changes of temperature. This statement appears, however, to From the fact that the indications of inexhaust all that can be said in favor of jury in the boilers of the Satellite and this system. Its practical disadvantages Conqueror were not greater, I would infer that the water used was fresh, or, at least, that the plates were entirely free from scale when the trials were made. When scale is formed on the plates to any extent, the injury from this mode of working becomes very marked. Altogether, it appears to me that this system of increasing combustion is, from its wastefuness and the defects I have mentioned, unsuitable for continuous working in any large steamer. For torpedo boats with one furnace, where the disadvantages are minimized, this system may hold its place, and as these boats are only occasionally used, waste of fuel is, therefore, in them

of small importance.

I now come to describe a system of increasing combustion artificially, which I devised during the year 1880, having been led to this arrangement by the remembrance of the causes of failure to obtain satisfactory results in 1862, already alluded to, and also by observing the defects of the different methods to which I have referred. In the summer of 1882 I had an opportunity of applying it to a small marine boiler, 7 feet diameter by 7 feet 9 inches in length, having two furnaces each of two feet diameter. The results being satisfactory, I constructed a boiler for the purpose of testing on a sufficiently large scale the various important advantages contemplated by the adoption of this mode of working. This boiler is 10 feet in diameter by 9 feet in length, with two furnaces, each 3 feet inside diameter. The furnace tubes extend the whole length of the boiler, the fire gases returning to the front from a dry chamber at the back end lined with fire-brick and otherwise protected from radiation of heat, through two separate stacks of tubes, each stack having 45 tubes, $3\frac{1}{4}$ inches external diameter. This boiler I erected in a yard by itself in July last, with evaporating tank, engine and fan, and other appliances suitable for testing results, and have since then been engaged more or less frequently in making trials under various conditions. The principal ends which I have endeavored to accomplish satisfactorily are:—

(1.) To effect with ease and certainty complete combustion of fuel in the furnaces of ordinary steam boilers at all rates from zero up to that of a locomotive boiler

if required.

(2.) To effect this combustion at all

fer that the water used was fresh, or, at rates, whether high or low, economically

as regards fuel.

(3.) To effect this economical combustion rapidly or slowly in boilers of ordinary character, either singly or in numbers, without any change in the usual conditions of stokeholds for boilers worked by natural draught.

(4.) To effect the foregoing purposes with less discomfort to the stokers and attendants, and with less wear and tear of the boilers and furnace fittings, than is experienced when working in the ordinary way with natural daught.

To attain the ends sought for under the first head made it necessary to use air under a pressure above the atmosphere, such as is conveniently got from a fan, with simple means of using more or less of this air as required. To attain the second point, that of economical combustion at all rates, it was imperative that the supply of air should not only be under perfect control, but that the necessarily varied quantities admitted per unit of time or of coals consumed, should be exactly ascertained; and, further, its distribution should be as nearly as possible equal over the furnace, and limited as nearly as possible to the theoretical quantity for the weight of fuel being consumed; finally, that the waste of the heat of combustion should be reduced to a minimum. To accomplish the third, it was necessary that the supply of air to any single furnace in a boiler, or to any boiler in a series, should be quite independent of the supply to the other furnaces or boilers. The advantages under the fourth head follow from the more economical combustion requiring less supply of fuel than would be necessary with natural draught, by the radiation of heat into the stokehold from the furnaces being prevented, and by the supply of air to the fan being made to circulate through the stokehold. The saving of tear and wear is due to the air being introduced to the furnace so as to preserve the furnace fronts and interior fittings, and also to the prevention of the usual injurious rush of cold air into the furnace when stoking, by suspending the air admission when a furnace door is open.

The manner in which I have endeavored to carry out these several purposes will be understood more clearly by the following description: On the front end of the boiler an air-tight chamber or resare the inner and proper doors of the more or less incandescent. separates the ash-pits from the furnaces dency to blow off. above the fire bars. Into these spaces admitted in the desired quantity from by separate valves.

of the air to different parts of the furnace is to reduce largely the rate of combusis kept under perfect control, the quanti- tion with a given pressure of air. ties admitted being ascertainable, and all natural draught this boiler, as described, radiation of heat from the furnaces or generates steam very slowly. With 2 ash-pits prevented. The heat of the fire inches to $2\frac{1}{4}$ inches of air pressure a comgases after they leave the boiler is largely bustion of about 30 lbs. per hour per utilized by causing them to pass up square foot of fire-grate can be reached. through the tubes in the air reservoir immediately above the smoke boxes, as a corresponding increase in outlet area, shown. While the hot gases pass through or by increasing the air pressure, but the the inside of these tubes, the cold air latter would be undesirable where the from the fan entering by the pipe is made former can be accomplished. Under the to sweep right and left among the tubes, restricted conditions described, the boiler

ervoir is formed of light plate iron, to carrying a considerable portion of the esreceive the air for combustion under caping heat downwards by the sides of pressure from a fan. This air chamber the smoke boxes to the furnaces. When extends over the whole front of the a furnace or ash-pit door is opened for boiler, from some distance above the up-stoking purposes, the air admission valves per row of tubes downwards, so as to en-for that furnace are closed, so that the close the furnaces and ash pits. The furnace may be operated on in a quiescent smoke-boxes of each stack of tubes are state. No rush of cold air can thus pass completely separated from the air cham- into the furnace, as in the air pressure ber by suitable castings, as are also the stokehold system, or even as in boilers furnaces and ash-pits, so that no air can worked by natural draught. The saving enter the furnaces or ash-pits except of the boiler from injury, and the preventhrough passages regulated from the out- tion of waste of fuel, by this means are side by valves. The upper portion of the important features. When it is desired reservoir extends outwards from the to reduce or increase the rate of combusboiler not more than the ordinary smoke-tion, the admission valves are opened or boxes and uptake; below, at the furnaces, shut as required, and with any given the reservoir in this case extends $7\frac{1}{2}$ pressure of air in the chamber, it is not inches from the boiler, but this may be difficult, after a few trials, to establish reduced. On the front of the castings the required openings for different rates which separate the furnaces from the air of combustion, from zero to the highest chamber, the outer furnace doors and rate possible by the given air pressure. ash-pit doors are hinged air-tight. At- When the admission valves are entirely tached to the outer furnace doors by shut the combustion may be practically studs, and moving on the same hinges, suspended for hours, the fires continuing By this furnaces, which shut on the inner front means a steamer may with ease be kept plate in the usual manner. A dead plate lying under any desired pressure of steam between the outer and inner front plates for any length of time, and without ten-

In erecting the boiler for trial, I purabove the dead plate and between the posely made the conditions under which outer and inner furnace doors the air is it was to work as difficult in regard to combustion as would ever be likely to octhe common chamber by simple plate cur under the most unusual circumstances valves, and after passing through perfor- in actual practice. The funnel was made ations in the doors, at the sides, and only 15 inches in diameter and 21 feet above the doors, is received into cast iron high from the fire grate. A still greater boxes, which serve the double purpose of restriction was the limiting of the air protecting the front plate and furnace heating tubes in the reservoir (through door from the great heat, and distributing which the whole of the fire gases issuing the air effectively among the fuel. The from each furnace have to pass to the air is admitted as required to the ash-pits common uptake) to fourteen in number of $3\frac{1}{2}$ inches external diameter. The ef-By these arrangements the admission fect of these restrictions and contractions This rate could evidently be doubled with

is worked with the utmost ease at any rate of combustion up to the limit mentioned, and with absolute freedom from smoke. In the numerous trials which have been made during the last seven months I have endeavored to ascertain the following particulars:—

(1.) The rates of combustion effected by admissions of air varying both in

quantity and pressure.

(2.) The effect of different quantities and velocities of air admission on evapor-

ative economy.

(3.) The most favorable modes and proportions of admission and distribution of air under different pressures.

(4.) The nearest approach to perfect combustion chemically at various pressures with the least possible admission of air.

It will be evident that the elucidation of these various particulars with tolerable accuracy requires a great number of trials, and as each trial is frequently of five or six hours' duration to ensure accuracy, a great expenditure of time is involved. Though the trials have been going on for the time mentioned at about an average of one per week, they are not yet so complete as to enable me to establish definitely the best proportions and velocities of air admissions above and below the fire-grate for all rates of combustion. can as yet only give approximations, though the conditions which yield the most favorable results are more or less ascertained. As I mean to continue these trials, I hope to be able to give fairly com. plete statements on some future occasion. At present the time at my disposal will only allow of a few remarks describing the mode in which the trials have been carried out. In ascertaining the effect of the admission of air above as well as under the fire-grate, trial was made with different areas of apertures, and of different pressures of air on equal areas. example the trials were begun with a limited aggregate area in the holes of the air-boxes inside the furnace, this area being gradually increased until it was found that the increased area added little to the rate of combustion, while the evaporative economy became sensibly reduced. The admission below the grate was also tried with various areas of air inlet apertures and pressures, and their effect noted on the combustion and evaporation.

esting results were noticed. For example, when the air admissions above and below the fire-bars were regulated in certain proportions to each other, if the admission openings above were then decreased, and those below increased to about the same amount, a much higher rate of combustion took place than when the process was reversed by increased admission above and decreased below. This difference arose from the changes produced in the balance of pressure in the furnace. When the pressure is relieved somewhat above and increased below, the air passes much more rapidly through the fuel in its passage to the chimney, with a correspondingly more rapid combustion, than it does if, with the same aggregate admission, the pressure is increased above and decreased below. In this case the current upwards through the fuel is greatly checked, and proportions could be so regulated that the current through the fuel could be nearly prevented by the pressure above. At the same time the admission of air above the fuel in proper proportions serves most important purposes, and contributes towards realizing the highest economy. has also an important effect in preserving the furnace fittings and fire-bars. I have referred to the great destruction of firebars caused by working with the closed ash-pit system. The cause of this destruction became evident to me after I had several trials with the new system I am describing, as in it the admission above the bars tempers the velocity of the air through the fuel from below, while the fuel is kept in perfect combustion above. When the pressure of air is entirely from below, as in the closed ash-pit system, with a sufficient depth of fuel on the grate and a given air pressure, the bars can be melted by the intense heat generated in the lower layers of the fuel. I find, on examination, the fire-bars and air boxes in the boiler I am operating with are still sharp on the corners, and as good now as when put in, after making with them all the trials I have mentioned, and consuming in some cases about 30 lbs. of coal per square foot per hour. This is an important practical result in the working of the furnaces with air under pressure.

The chief point, economically, towards which I have been working in these trials is the attainment of a high rate of com-In the course of these trials some inter- bustion with a minimum admission of air,

that is, an admission as near to the theoretical limit as can be practically reached. This is no easy matter, and requires to be worked towards step by step. The trials would have been in great measure a groping in the dark, even with the appliances described, but for the apparatus devised to ascertain by measure of the quantity of air entering at different parts of the furnace above and below the firebars at the various pressures used. This device, which occurred to me after several trials were made, is the application of an anemometer, with an apparatus in which the same conditions as to entering and back pressures are created as those which exist in the part of the furnace into which The velocity the air is being admitted. is read off without difficulty, and the dimensions of apertures being known and temperature ascertained, the volume of air is exactly calculable. The system of measurement, combined with chemical analysis of products of combustion, enables one to work with intelligence and certainty. These trials have strikingly shown the great difficulty of obtaining a high rate of combustion with forced blast, without admitting a most wasteful excess of air. It is comparatively easy to obtain a high rate of combustion, but very difficult, unless suitable adaptations are used, to combine a high rate of combustion with economy. In the small boiler, which I first tried with a very complete combustion, the evaporation was very low per lb. of coal, entirely owing to the excess of air. In the present boiler the evaporation has already reached a very fair economy, though not within a considerable amount of what is yet almost certain to be attained.

What has already been accomplished shows that from $9\frac{1}{2}$ to 10 lbs. of water, at 212°, could be evaporated in boilers at sea, from 1 lb of Scotch coal, with a rate of combustion of 30 lbs. per square foot of grate per hour; but there are good grounds for expecting that an evaporation of even 12 lbs. may yet be reached with a rate of combustion from 40 to 50 lbs. per hour per square foot of grate. It should be explained that the boiler I have used for these trials, with the furnace arrangements described, is not intended to represystem of combustion. It is merely a boiler suitable for ascertaining results un-

der various conditions. There are several changes now being made in the fittings in the light of the results already accomplished, which will, without doubt, increase the evaporative economy without reducing the rate of combustion. Compared with the working of boilers by natural draught, the advantages which this system of combustion by air under pressure gives may be summed up as follows:

(1.) Complete combustion of fuel of all qualities, under conditions in which combustion could not efficiently be obtained

by natural draught.

(2.) The power of regulating with ease the amount of combustion desired from zero to many times that possible by natural draught, also the capability of maintaining the fuel in the furnace incandescent for a considerable time without appreciable consumption.

(3.) A great reduction in the size or number of boilers required to produce a given power and the capability of increasing the power in steamships far beyond that now attainable with boilers worked

by natural draught.

(4.) Greater economy in producing steam from the following causes—(a)From more complete combustion of fuel than is attainable by natural draught with a reduced admission of air. (b) From the higher temperature of the furnace arising from the more perfect and higher rate of combustion, and from the air supply being partially heated before entering the furnace. (c) From the utilization of the waste heat of the escaping gases. (d) From the prevention of heat from the furnaces and ash-pits being radiated into the stokehold. (e) From the much less expenditure required to supply the air of combustion from a fan than is required to heat a column of air in a chimney to obtain supply by natural draught. (f) From preventing the cooling down of the boiler by a rush of cold air to the furnace when a furnace door is opened.

(5.) Less discomfort in stoking, the stokehold being kept fresh and cool by by the radiation of heat from the furnaces being prevented, and the fan drawing fresh air into it continuously independent-

ly of ventilators.

(6.) The complete absence of the great sent the best mode of carrying out this nuisance of smoke in the use of steam power.

(7.) The abolition of all unsightly

chimneys in town and country now necessary for combustion by natural draught.

The economic advantage of supplying the air of combustion by mechanical means, instead of by the rarefying of a column of air in a chimney by heat, as in natural draught, is given in the concluding illustration. I close this paper by giving an example of the reduction which (basing on there sults I have already attained) may with safety be made in the number and dimensions of boilers in large ocean steamships. I take, for comparison the Oregon, the latest of the large high-speed Atlantic liners. The published accounts give the boilers as nine in number, each 16 feet 6 inches diameter, length 18 feet, with eight furnaces, or seventytwo in all, each 3 feet 6 inches in diameter. Fire-grate, 6 feet in length, making a total fire-grate of 1,512 square feet. Proposed indicated horse-power, 12,000; assumed consumption of coal per indicated horse-power per hour, 2.6 lbs. consumption per hour being thus 31,200 lbs., or 13.92 tons. I have here assumed the consumption per indicated horsepower at 2.6 lbs. per hour, without inquiry, as there might be reasons for her owners or builders withholding this information. It is well known, however, that the high speeds in these large steamers are only maintained by a considerable sacrifice of economy; and I have, on the authority of the managing owners of another high-speed Atlantic steamer of about same size and power, that 2.6 lbs. does not over-state the rate of consumption in their experience. am not aware that 12,000 indicated horsepower has been actually attained in this steamer at sea, but if it has, it could only be attained by stoking of the most severe character. The enormous space occupied by these boilers and by the coal bunkers can easily be calculated from the above particulars.

Using data already verified by actual trial, the boilers, which, on the system of combustion I have had the honor to bring before you, would easily supply steam to the engines sufficient to develop 12,000 indicated horse power, would be six in number, 15 feet in diameter, with six furnaces only in each boiler, or thirty-six in all, each 3 feet 9 inches diameter. The fire-grate 4 feet 6 inches long, making an 300° higher in the former case than aggregate of 641.25 square feet of grate. in the latter, as explained) are therefore

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The consumption of coal in the engines working from the boilers, I believe I may safely assume as 1.6 lb. per horse-power per hour, seeing there are engines which approach this rate of consumption supplied with steam from boilers worked by natural draft, having a lower evaporative economy. The consumption of coal at this rate is therefore $12,000 \times 1.6 = 19,200$ lbs., being 8.57 tons per hour, or 320 lbs. per minute. In comparing the expenditure incurred in supplying the air for combustion by an engine and fan in the one set of boilers with that incurred by supplying the same by natural draught in the other of these two sets of boilers, I will assume that the air supply to the furnace per lb. of coal consumed is the same in both cases, though the reduction of the air admission is one of the chief objects of my system of mechanical supply. Assuming the air supply to the furnace to be at the very moderate rate of 15 lbs. per lb. of coal consumed, and that the temperature of the escaping gases of the boilers with mechanical supply is 300° less than the escaping gases of the boilers with natural draught, we have now the means of calculating the required expenditure of each form of air supply. difference in temperature I assume, because it would be realized in practice. One of the essential points in this system of forced combustion is the reduction of the temperature of the escaping gases to a point far lower than would be possible in such boilers worked by natural draught.

Taking first the boiler with natural draught, consuming 31,200 lbs. of coal per hour, or 520 lbs, per minute, we have the weight of air supplied to the furnaces for combustion $520 \times 15 = 7,800$ lbs., to which has to be added the gaseous products of combustion, or the weight of coal less. the ash, which, if taken at $7\frac{1}{2}$ per cent, will give $7,800\times(520-39)=8,281$ lbs. as the total weight of gaseous products passing up the chimney per minute, from the combustion of 520 lbs. of coal. With the specific heat of the escaping gases at .246, the total units of heat wasted or expended in obtaining the power of combustion by natural draught beyond that required to supply air by a fan (the temperature of the escaping gases being $8,281 \times .246 \times 300 = 611,137$ units less the equivalent of the power required for the fan supply. The mechanical equivalent in horse-power of these 611,137 units of heat is $\frac{611,137 \times 772}{33,000} =$

14,296 horse-power. This, of course, supposes the total heat converted into work, and expressed in horse-power units. The actual value of this expenditure of heat is correctly stated in the ratio of the economy of the engines and boilers, which, at 2.6 lbs. per indicated horse-power per hour, is very nearly a utilization of one-twelfth of the total heat of combustion of coal of average quality; therefore, 14,296÷12=1,191 is the actual horse-power equivalent of the 300° heat lost in maintaining the temperature of the funnel in the natural draught boilers.

Coming now to the boilers with the mechanical supply of the air of combustion, and consuming 19,200 lbs. of coal per hour, or 320 lbs. per minute, and taking the weight of the air supplied per lb. of coal at 15 lbs., as in the natural draught boilers, we have $320 \times 15 = 4,800$ lbs. of air supply required per minute for the combustion of 320 lbs. of coal. The volume required at 60°, or 13 cubic feet, per lb., is, therefore, $4,800 \times 13 = 62,400$ cubic To supply this volume per minute from three fans, each having discharge orifices 30" diameter, or 6.25 square feet area, giving a total area of 18.75 square feet, a velocity of 55.46 feet per second is required, as $18.75 \times 60 \times 55.46 = 62,400$. The horse-power required to supply this weight of air at this velocity per second

is found by the usual formula, $\frac{w \cdot v}{2 g}$. Here W= $\frac{4,800}{60}$ or 80 lbs. air per second,

and $\frac{80 \times 55.46^2}{64}$ = 3,845 footlbs.,persecond, and $\frac{3,845}{550}$ = 7 horse-power nearly. This

7 horse-power is the power required to supply the whole air of combustion for 12,000 indicated horse-power, supposing perfect efficiency in the fans, and in the engines that drive them. Assuming 75

per cent. efficiency in the engines, and 50 per cent. in the fans, we have $\frac{7\times100}{75}$ =9.3' and $\frac{9.3'\times100}{50}$ =18.6 as the gross

horse power for supplying the total air of combustion to the furnaces mechanically.

This 18.6 horse-power as against an expenditure equivalent to 1,191 horse-power (required to maintain a temperature in the funnels necessary to give a sufficient supply of air by natural draught to boilers supplying an equal quantity of steam), shows the vastly superior economy of the mechanical supply of air to boilers, if this air is otherwise judiciously used. The reduction in the weight and number of the boilers, of the space occupied in the vessel, and the saving of coal in a vessel of the power of the Oregon, and proportionately in other large steamers, by the adoption of the system of combustion I have endeavored to explain, could not fail to effect the commercial character of these large vessels to a very remarkable extent. The considerable increase recently attained in several new large passenger steamers over the highest speeds previously prevailing has only been reached at very great cost. The principal carrying part of the vessels is filled with boilers and coals, and the expenditure in this department in forcing the vessels to their speed is seriously extravagant. To attempt a still higher speed with the present system of natural draught would be commercially ruinous, even if physically possible. The system of combustion in boilers which I have had the honor to bring before you would not only, I believe, permit the highest speed yet attained to be maintained with comparative ease and economy, but would also, I am convinced, allow of still higher speeds being commercially possible.

REPORTS OF ENGINEERING SOCIETIES.

The Institution of Civil Engineers.—The Council have awarded the following premiums in respect of the original communications submitted during the session 1883-84:—

For Papers Read at the Ordinary Meetings. 1—A Watt Medal and a Telford Premium to Sydney Walker Barnaby, Assoc. M. Inst. C.E., for his paper on "Hydraulic Propulsion."

for his paper on "Hydraulic Propulsion." 2—A Telford Medal and a Telford Premium to Samuel Bagster Boulton, Assoc. Inst. C.E., for his paper on "The Antiseptic Treatment of Timber."

3—A Telford Medal and a Telford Premium to William Foster, M.A., F.C.S., for his account of "Experiments on the Composition and Destructive Distillation of Coal."

4—A Telford Premium to William Tregarthen Douglass, Assoc. M. Inst. C.E., for his description of "The New Eddystone Lighthouse."

5—A Telford Premium to James Atkinson Longridge,* M. Inst. C.E., for his paper on

"Wire Gun Construction."

6-A Telford Premium to William Hackney, B.Sc., Assoc. M. Inst. C.E., for his paper on "The Adoption of Standard Forms of Testpieces for Bars and Plates."

7—The Manby Premium to George Henry Stayton, Assoc. M. Inst. C.E., for his paper on "Wood Pavement in the Metropolis."

For Papers Printed in the Proceedings without being Discussed.

1—A Telford Medal and a Telford Premium to Thomas Andrews, Assoc. M. Inst. C.E., F.R.S.E., for his paper on "Galvanic Action between Wrought Iron, Cast Metals, and Various Steels, during Long Exposure in Seawater."

2—A Telford Medal and a Telford Premium to Francis Collingwood, M. Inst. C.E., for his paper "On Repairing the Cables of the Allegheny Suspension Bridge at Pittsburgh, Pa.,

U.S.A."

3—A Telford Premium to James Henry Ap-john, M.A., M. Inst. C.E., for his note on "The Area of Sluice-opening necessary for the Supply Sluice of a Tidal Canal."

4—A Telford Premium to M. Inst. C.E., for his paper "On the Basic, Open-hearth, Steel Process."

5—A Telford Premium to James William Wyatt, Assoc. M. Inst. C E., for his communication "On the Art of Paper-making by the Machine, as Exemplified in the Manufacture of High-class Writings and Printings."

6—A Telford Premium to William Santo Crimp, Assoc. M. Inst. C.E., for his account of

"The Wandle Valley Main Drainage."

For Papers Read at the Supplemental Meetings of Students.

1—The Miller Scholarship to Alfred Richard Sennett.‡ Stud. Inst. C.E., for his paper "On the Electric Light."

2-A Miller Prize to Peter Chalmers Cowan, Stud. Inst. C.E., for his notes on "The New York, West Shore, and Buffalo Railway and the Methods used in its Construction."

3—A Miller Prize to Walter Osmond Rooper, Stud. Inst. C.E., for his account of "Emery Wheels, and Emery-wheel Machinery."

4—A Miller Prize to Richard Moreland (tertius), Stud. Inst. C.E., for his paper on "Constructional Ironwork for Buildings."

4—A Miller Prize to Edward Woodrowe Cowan, Stud. Inst. C.E., and a Miller Prize to James Fawcus, Stud. Inst. C.E., for their joint paper descriptive of "A Light-draught Launch."

ENGINEERING NOTES.

LARGE planing machine in the Charles-A town Navy Yard, at Boston, built in 1866-69 by S. Wilmarth, is described by the Boston Globe as the largest one in the world. "Its total weight is 300 tons; extreme length, 55 ft.; width, 31 ft.; height, 29 ft. It will plane a piece of metal 18 ft. square and 45 ft. long. It will also plane at right angles or vertically. It will plane a piece weighing 200 tons if required the medium of G. G. Maranzoni, of Venice, has

at any given angle, and is capable of boring, turning, slotting, or splining to a depth of 4 ft. and at any taper indicated. The lightest class of work is accomplished with great rapidity and accuracy. Among other specialties it will bore, turn, and cut gear wheels of any required size up to 40 ft. in diameter. It will bore and spline propellers of any size and weight.'

THE WATER SUPPLY OF VENICE.—Those who have stayed in Venice have learned what it means to be dependent for water upon an army of men, who with barges fetch a daily, or rather nightly, supply of liquid, rarely fit to drink, across the lagoons from a stream emptying near a place called, if we remember correctly, Servola. These old travelers, and those who have yet to visit that much-visited city, will be glad to learn that the inauguration of the Venice Waterworks, by which a real pipedwater supply is carried into the romantic city, took place on the 23d of June last, and fully realized the expectations of all concerned in this piece of hydraulic engineering, which is internationally interesting. The contract for the works has been carried out by the Public Works' Company of Italy—Messrs. Breda & Co. including the construction of the reservoir and filter beds at Moranzano on the mainland, and the laying of the pipes under the Laguna to the city of Venice of a total length of 6,460 meters, of a diameter of 80 centimeters—31. 5 in.—and the laying of the total length of mains in the thoroughfares and canals of 25,706 meters of a diameter of 30 centimeters—11. 8 in. In the course of laying these mains they were taken at cighty-five places across canals, and twice across the Grand Canal, work which involved considerable difficulties. The work also included the construction of an engine house and reservoir at St. Andrea, the erection of a pair of 50 nominal horse-power engines, together with laying on the water to all the principal buildings and hotels in the city. The work was commenced early in January, 1881, and was consigned to the entire satisfaction of the concessionaires on the 23d of June, 1884. concession was originally granted to Mr. D. C. Dalgairns, C.E., of Palermo and Penge, in 1876, upon provisional plans and studies then deposited, and the works have been carried out on the definitive plans presented by him on the 23d of June, 1877. The company to which the property now belongs is the Sociétié des Eaux pour les Etrangers, of Paris, which was formed for the purpose of carrying out this scheme in January, 1879. Probably no city in the world had more urgent reason to obtain and maintain an excellent water supply than Venice. Venice lives upon the pleasures of all the nations of the world, and she could not afford that the fearfully bad supply upon which she has depended from time immemorial should drive away even a few hundreds of the many thousands of her visitors. She has therefore gone to the Brenta for water, and now her visitors may at any time, instead of occasionally, have a glass of water to drink, or may even have a bath. Count Dante Serego degli Allighieri, the Sindaco of Venice—a descendant of Dante—through

expressed his deep sense of gratitude to Mr Dalgairns on the successful inauguration, and adds, "The city of Venice is truly alive as to its indebtedness."-Engineer.

IRON AND STEEL NOTES.

F. Mushet on Blowholes in Steel and Cast Iron.—The creators of the age of steel have ransacked creation to find methods of preventing or lessening, or altogether stopping, these blowholes, with more or less success, but with a great deal more of failure. As Mr. W. H. Fryer has justly observed, these cells are formed or inflated by hydrogen gas. Take away now that gas, and you will take away the cells; but as long as blast furnaces and Bessemer converters are blown with damp atmospheric air, the hydrogen and the blowholes will more or less be there. Why not dry the air, and try the matter fairly? The drying can be cheaply effected for, I suppose, 3d. or 4d. per ton of metal; but nobody appears to have tried the process yet, although it has been before the public, I think, for over two years. It is true that under the withering blight of that enormous sham called "free trade" iron and steel makers have so much to do to hold their own, and to grind down workmen's wages to the lowest point, that they have not time or money to spare to pay attention to improvements, however valuable and useful they may be. The dry blast, however, is well worthy of a fair trial, both in the blast-furnace and in the Bessemer converter. Iron and steel can only get their hydrogen from the blast, and if that blast is desiccated, no hydrogen can be present to form cells. To take pig-iron made—as all of it is at present—with damp blast, and blow it in a Bessemer converter with dry blast, would not be conclusive, for both the blast-furnace and the converter should be blown with dry air, so that no hydrogen could possibly be present.

I have said that the drying is inexpensive, say 3d. per ton; but I had forgotten for a moment that even one penny per ton is a serious amount under our free trade prosperity, which is eating like a cancer into every manufacture, cutting down profits to zero, and, therefore, annihilating capital and wage-paying power. There is a ludicrous phrase, dear to the soul of the Cobdenite. "Holding their own" is their panacea. If anyone can hold their own, that is, just struggle on, short of a composition or bankruptcy, the Cobdenites record it with pleasure. Formerly, employers of labor looked for profits; now, if they can "hold their own," they must be content. The very colliers are not safe from the devouring maw of free trade, for coal is being imported! Even the poor colliers have to hold their own, if they can. When will the petrified fossillized generation of Cobdenites pass away, and so give home industries a chance to thrive once more? Free trade has desiccated home industries, and given the bread of the British workmen to foreigners.

To Tell Iron from Steel, in Small Pieces.

—A new fracture ordinarily furnishes the

with good, fine-grained iron or very soft steel. In order to effect the separation with ease and certainty in such cases, Walrand has given a simple method in the *Memoires de la Societé des* Ingenieurs Civils, 1883, page 531. It is by observing the fracture of the test piece after heating and allowing it to take a blue color. The trial can be conducted in the following manner. Take a test piece about twenty-five or thirty centimeters long and make a slight scratch about four or five centimeters from the end. Then heat one end slowly and uniformly to a dark red color (325° to 400° C.) and cool it in water. During the cooling, while the piece is still warm, it must be rubbed with a file from time to time, until the shining metallic surface laid bare, has assumed a dark yellow, or better, blue color, when it is to be cooled quickly and completely. The fractures of the piece broken at the mark serve for comparison. Ordinary wrought-iron broken when cold appears fibrous or crystalline; but, treated as above, its fracture is dull, irregular, and of short fibre. Hard and moderately hard steel are fine grained; after the heating and subsequent treatment, they have a shining, totally or partially, smooth fracture. Swedish iron has only traces of fibers and is hardly to be told from soft steel; after treatment the fibers become distinct, the smooth appearance is lost, and the iron becomes so much the more distinguishable from soft steel treated in the same manner.—Dingler's Polytechnisches Journal.

PESTS OF IRON AND STEEL GIRDERS.—Some very accurately conducted experiments were recently made by the Dutch government to test the relative strength of iron and steel girders. Hard and soft steel girders were put in comparison with iron girders of a good quality. The tests were made by specimens of the materials from which the girders were made, and also by actual finished girders. Each of the steel girders showed a large increase in strength over the iron girder. The soft steel girders proved 22 per cent. stronger, and the hard steel girders as much as 66 per cent. stronger. The greater strength of the soft steel over the iron in the specimens submitted was fully attained, and even exceeded, in the girders. The hard steel girders did not show so large a percentage of greater strength over the iron girder as did this material in the specimen over the iron in the specimen. This, however, may be accounted for as the result of punching the rivet holes without reaming, for a girder with punched holes gave way during the trials by a fracture of the tension flange, whereas a girder with reamed holes gave way in the compression flange, and probably would have stood more before fracture had taken place in the tension flange. The latter girder did not appear to bear truly upon its supports, and it was prabably this which caused it to fail in the top flange when it did. Punching rivet holes without reaming did not produce any results other than an apparent loss of strength, as compared with reamed holes. The trial pretty well established that the strength of steel girders, strained means for classifying test pieces, but its appearance is not a sufficiently safe guide in dealing flanges if they are made alike in section.—Iron.

RAILWAY NOTES,

TT is stated on official authority that there are now 3,000 miles of railway in operation in Brazil. There is scarcely a province bordering on the ocean that has not one or more railways, and all lead to the west, or toward the interior. In the most southerly province, Rio Grande do Sul, the Porto Alegre Railway, now open 91 miles to Cacheira, is being built by the State, and partly for strategic purposes. Steady increase has been lately made in extending several lines; new lines have also been commenced, and there is reason to suppose that the development will annually increase, though the broken surface of Brazil generally, and especially the mountains near the sea-coast, are great obstacles to the rapid development of railway construction. None of the railways have yet penetrated to the vicinity of wild or public lands. Some of them traverse extensive areas of uncultivated land, but as yet no grants of land have been made in aid of railways. The Brazilian Government, however, has extensively guaranteed the payment of interest on railway capital. Its annual burden for the payment of such interest amounts now to a very large sum. The rails for all the lines have to be imported, and the greater part are purchased in England. Many of the locomotives are imported from the United States. It may be also mentioned that several American civil engineers have gained distinction by their services in Brazil, but the field now appears to be occupied by native talent. At the same time, several English railway companies naturally employ English engineers.—Engineer.

GREAT RAILROAD EVENT IN SOUTH AMERICA. -A great event in Buenos Ayres has been the recent completion of the Andine Railway to Mendoza, capital of the province of that name, and lying at the foot of the Andes. The importance of this event cannot be exaggerated; the line, it may be said, crosses the continent, stretching from the Parana to the Cordillera. A zone of immense natural wealth is thus thrown open by this quick means of communication, and the traffic on the line promises to be very large. Mendoza is one of the richest provinces of the republic; it covers an area of about 5,000 square leagues of land at the foot of the Andes, with a population estimated at 150,000 souls. The rivers Mendoza, Tunuyan, Desaguadero, Diamante, and Atuel irrigate over 1,000 square leagues of land, and the soil is so bountiful that the yield is often a hundredfold. A very active trade is carried on in the export of fat cattle to Chili, but the great industry of the present and future is viniculture. Mendoza wines are well known; the production is doubling every two years. The great draw-back of the past—onerous and difficult means of communication-is now removed, and the development of all the industries of the province may be looked forward to. The mineral wealth of the province is said to be beyond calculation. -Iron.

Russian government to forthwith set up works within its frontiers for the manufacture of Wilson's compound armor plates. The armor for the several railway companies in the United to the French ships Duguesclin, Vauban, Requin,

Kingdom during the first three months of the present year, together with reports of the inspecting officers of the railway department to the Board of Trade upon certain accidents which were enquired into. Among the accidents reported were 10 collisions between passenger trains or parts of passenger trains, by which 120 passengers and four servants were injured; 14 collisions between passenger trains and goods or mineral trains, by which 13 passengers and four servants were injured; nine collisions between goods trains or parts of goods trains, by which two servants were killed and seven injured; 16 cases of passenger trains or parts of passenger trains leaving the rails, by which two servants were killed and four passengers and four servants injured; and 32 cases of trains running over cattle or other obstructions on the line, involving injury to four passengers. The total number of persons killed on railways in the United Kingdom in the course of public traffic during the past three months was 254. The injured numbered 990. This is a decrease as compared with the corresponding period in 1883.—Éngineer.

ORDNANCE AND NAVAL.

TOMPOUND ARMOR PLATES.—The Danish Government, following the example set by England, France, Italy, and other maritime powers, has decided in favor of the adoption of English compound armor plates, as superior to all others for the protection of ships against modern rifled ordnance. This was only to be expected. It would, indeed, have been surprising to find a government such as that of Denmark arriving at any other conclusion, after the experience gained at the trials which have been made throughout the world of iron, steel, and compound armor plates. The latter have invariably proved superior to all other means of protecting a ship's side, and, although it was at one time thought that the influence in Copenhagen of the French Creuzot works was powerful enough to influence the Danish government to use solid steel plates to protect their ships, the final decision arrived at last week shows that the Danes are determined to use the very best material they can procure, irrespective of its nationality. It will be remembered that at the last trials on the island of Amager, near Copenhagen, both the Ellis and Wilson systems of facing iron plates with steel were tried. The Danes have now decided to adopt the latter system, as being, in their opinion, superior to the former. It has come to be admitted by all naval powers that compound armor is far better able to withstand the heavy blow of the projectile thrown by modern ordnance than are either solid steel or iron plates; and, since steelfaced plates are solely made in Sheffield, this English industry will be busy for many years to come. Russia, however, is alive to the advantages of producing at home all the material required for its navy; and Messrs. Cammell & Co. have recently received an order from the Russian government to forthwith set up works within its frontiers for the manufacture of WilCaiman, Admiral Baudin, Dupere, Furieux, and Tonnerre, is being made in France on the Wil-That of the Indomitable was son system. manufactured in Sheffield by Messrs. Cammell & Co.; as were also the plates for the Russian Vladimir Monomach, the Chinese Chen-Yuen, the Braziliac Riachuelo, the Italian Italia, and many other modern ships of foreign governments. Our Admiralty use both Wilson and Ellis compound plates, it not being deemed expedient, where so many ships are constantly in course of construction, for the government to be solely dependent on one firm.—Army and Navy Gazette.

MACHINE GUNS IN THE FIELD.—At the meeting of the Royal United Service Institution, held on July 4, Capt. Lord Charles Beresford, R.N., read a paper on the above subject. There were several specimens of those weapons on the floor of the theatre—a Gatling, with ten barrels, worked by means of a crank; a two-barreled Gardner, and a couple of Nordenfelts, one of them mounted on a carriage complete.

Lord Charles Beresford said that, as a naval officer, he had a certain amount of hesitation in taking up a question which officers of the army might naturally think belonged peculiarly to themselves. At the same time, it must be remembered that the navy had had more actual experience in the working of machine guns in the field than any other portion of Her Majesty's service, and guns for this purpose were supplied to the navy, but not to the army. A machine gun proper was a gun without recoil, or, in other words, was a weapon which did not There were require re-laying after every shot two entirely distinct kinds of such guns; the one a shell-firing gun, and the other a bullet-firing, or rifle-caliber, gun. International law did not admit of any explosive projectile under 14 ounces in weight, and the weight of a machine gun throwing such a projectile would detract from its value as a machine gun, and would make it almost artillery. Dealing with the small-bore caliber gun, to which he should confine himself, Lord C. Beresford discussed the recent trials at Poona of a ten-barreled Nordenfelt, and showed that the results were equal to the fire of seventy men with rifles, and 80 per cent. better than the hits from four 7-pounder mountain guns. He pointed out the value of the guns to the landing party at Alexandria in 1882, and proceeded to demonstrate the value of the weapon to artillery, cavalry, or infantry. He quoted the words of eminent military men in all branches of the service, giving some cases where guns had been of value, and others where days would have been saved and reputations upheld by the presence of a couple of machine An instance was at Maiwand, where, he said, if there had been any machine guns the guns would never have been lost, the cavalry would never have been kept so many hours inactive under a heavy fire, and the day would have been saved. He described the machine guns mounted on galloping carriages, and mentioned a few engagements in which the English troops had been fighting where a machine gun mounted as described would have been of infinite service. He urged that it would be better to do away with the limber altogether, and com- eaux; Distribution of trees in Norway; Con-

mented severely upon the disaster likely to result from a mixture of ammunition, quoting an instance where a box of Gatling ammunition got mixed with the ordinary ammunition, and where if the men had attempted to use the cartridges, the result would have been that every rifle would have been virtually spiked, as the discharged cartridges could be got out only with great difficulty. In conclusion, Lord Charles Beresford said that the machine guns of the present day are accurate, rapid in their fire, and terrible in their man-killing power is beyond doubt; whether they can or cannot be better utilized for the services is a grave question for consideration. For volunteers they would appear to be admirably adapted, and the London corps under Colonel Alt have lately demonstated (as far as drill can do, and in the recent sham fight at Portsmouth) how exceedingly useful they might be. Artillery officers, as a rule, are supposed not to look upon them with favor, but most of the arguments used against them appear to treat them as guns instead of clusters. of rifles, which they really are. In the course of a discussion which followed, Admiral Boyes expressed the opinion that it was a sine qua non that the ammunition for machine guns should be the same as for guns used in the field. Captain Colomb remarked that the navy, to a man, considered that the age of the machine gun was just commencing. Major Lewis re-ferred to instances where single-barreled machine guns would be most useful. Other officers also took part in the discussion.

BOOK NOTICES

PUBLICATIONS RECEIVED.

TEMPERATURE OF THE ATMOSPHERE AT THE EARTH'S SURFACE. By PROF. WILLIAM EARTH'S SURFACE. By PROF. WILLIAM Washington: Government Printing Ferrel. Office.

L' Assainissement Suivant le Système War-ng. Paris: Baudry et Cie.

Papers of the Institution of Civil Engineers: No. 1927. The Canadian Pacific Railway. By J. C. James and Allan Macdougall.

No. 1988. The Alleghany Suspension Bridge. By Francis Collingwood, M. Inst. C.E. No. 1966. Wandle Valley Main Drainage. By

William Santo Crimp, Asso. M. Inst. C.E. No. 1958. Wire-Gun Construction. By James

Atkinson Longridge, M. Inst. C.E.

No. 1968. Hydraulic Propulsion. By Sidney Walker Barnaby, Asso. M. Inst. C.E. Proceedings of the Engineers' Club of Phila-

delphia.

ORESTRY IN NORWAY. Compiled by JOHN CROUMBIE BROWN, LL.D. London; Simpkin, Marshall & Co.

The student of Physical Geography will find much to interest and to instruct in this little volume. All the conditions of climate and soil that influence the growth of vegetation are fully

How completely the physiography of Norway is presented, may be inferred from the following list of chapter headings; General features of the country; Forest Scenes; Mountain Platditions upon which distribution depends; Conditions of distribution in Norway; Temperature; Rainfall; Rivers; Lakes; Winds; Geological Formations: Mountains and Fields; Snow fields and Glaciers; Mechanical action of Glaciers: Saeter life; Valleys, Forest Exploitation, and the Timber Trade; Shipbuilding and Shipping; Forest Devastation: Remedial Measures.

This is one of the lesser contributions to the literature of Forestry from the pen of this industrious writer, but it will be widely read for the

information it affords on other topics.

UIDE DER NIVELEUR. Par J. VERRINE.
Paris: Paul Dupont.

The different methods of leveling, from the rudest to the most finished, are elaborately de-

scribed in this little book.

The instruments are classified as of three kinds, the builder's level and the old water level representing the first class; the pendulum level and the reflecting level, the second class, and the engineer's telescope level the third class.

Two full chapters are devoted to the different forms of rod and the errors to which they may

respectively give rise.

Section and cross-section work with notes, profiles and graphic solutions of earthwork problems form the matter of the four conclusive chapters.

Nearly two hundred illustrations are inter-

spersed throughout the text.

A TREATISE ON PRAOTICAL MINE VENTILA-TION. By EUGENE B. WILSON. New York; John Wiley & Sons.

The anthor of this little treatise explains in his preface that he "has endeavored to deal with ventilation in such a manner that no one with a fair knowledge of the English language and of arithmetic need despair of thoroughly

mastering it.

"Knowing that the miner possesses but a comparatively small stock of words, and is not an adept in algebraic formulas, the writer has taken a different position from the standard works on the subject, endeavoring to do away with abstruse language, and such highly mathematical formulas as are only calculated for well educated engineers."

The omission of abstruse language has been fairly well observed, but in some instances at a large expense of accuracy. For example, the author says of oxygen, "It devours everything with which it can unite; it corrodes metals, decays fruits, promotes combustion, and is a

prime necessity for health.

"The body is a stove in which fuel is burned; the chemical action being the same as in any

other stove."

Again on page 25 occurs the following; "The 'motive column' is a 'head of air" of such a height that it will equal the difference between the weight of the downcast and upcast columns of air."

This is followed by an incorrect formula:

$$\mathbf{M} = \mathbf{D} \times \frac{t - t_1}{459t + t_1}$$

The explanation is furthermore afforded that

"The relative diameters of the shafts make
no difference upon the total pressure, so far as

"The explanation is furthermore afforded that is an enthusiast, and as he is conscious truth of his statements, conviction that right will follow from a perusal of them.

the considerations regarding ventilation are concerned. This is termed the 'pneumatic paradox.'"

All that is not abstruseness in this last paragraph is misinformation. It should, however, be stated in justice to the author that the illustrated examples serve in most cases to set the reader right, and would prevent the learner, if he followed the arithmetical examples, from serious practical mistakes.

A faulty definition, however, may lead the student astray to his future disadvantage. Such

an one appears on page 47:

"Coefficient of friction is a term used to represent the constant resistance met with by air during its journey through the mine."

The typography and the arrangement of the

formulas are exceedingly good.

ORGHUM: ITS CULTURE AND MANUFACTURE, ECONOMICALLY CONSIDERED AS A SOURCE OF SUGAR, SYRUP AND FODDER. By PETER COLLIER, Ph. D. Svo, cloth, Cincinnati, R. Clarke & Co.

The development of an important industry is an achievement deserving of great honor, and so when an American chemist establishes on a solid basis a new American industry, unquali-

fied praise is due to him.

In 1877, at the request of the head of the Agricultural Department at Washington, D. C., Professor Collier undertook the examination of Sorghum and maize as sugar-producing plants. Since that time much of his ability and energy has been devoted towards the practical solution of these questions, with special reference to Sorghum. The different annual reports of the chemist give the results of careful investigation and show a steady progress in his work. periments were made for the purpose of determining the best varieties of the plant for cultivation, the conditions of soil, the effect of fertilizers, the most suitable forms of machinery. These and other like topics came up for consideration and were successively studied. Before long, factories were established at various localities throughout the country. Certain of these were unsuccessful while others flourished until, in 1882, the statistics given in the annual report of the Agricultural department for that year show a production of 510,780 lbs. of sorghum sugar. In 1883, upwards of 850,000 lbs. were reported, and to-day probably more than 1,000,000 lbs. are being manufactured. According to the census returns of 1880 the production of sorghum syrup is given as 28,444,202 gals., while in 1860 only 6,749,123 gals, were obtained. Such, in brief, is the history of the development of sorghum sugar industry.

In the book before us, we find arranged in the most admirable order, a discriminating and judicious selection from the information which Prof. Collier has accumulated from his experience and researches. In his own words it includes "the most important facts relating to the economic production of sugar, syrup, and fodder from sorghum." As an authority on this subject, the author stands second to none. He is an enthusiast, and as he is conscious of the truth of his statements, conviction that he is wight will follow from a new selection that he is

Prof. Collier has done much to benefit his fcllow citizens, he has also suffered severely from adverse criticism. It will be the mission of this book to widen and extend his influence, to increase his reputation, and to bring about a full realization of his most sanguine hopes for the sorghum industry.

TEXT-BOOK OF DESCRIPTIVE MINERALOGY.
By HILARY BAUERMAN, F. G. S. London:
Longmans & Co.

We have here a descriptive treatise on mineralogy, though only the more important species, scientifically or economically speaking, are de-

cribed in detail.

The subject of nomenclature is considered at some length. The author remarks that "names founded on physical or chemical peculiarities are, as a rule, among the most uncouth and inconvenient, and as they are not unfrequently founded upon false analogies, some trivial character, or one that may be common to many other minerals being selected as a specific distinction, a knowledge of their etymology is not always of advantage as an aid to the memory." Mr. Bauerman holds, very judiciously, that in the case of minerals worked as ores the ordinary commercial names should always be used where possible. "Thus for all purposes copper-pyrites, tinstone, and zinc-blende are preferable to calkopyrite, cassiterite, and sphalerite."

The author's classification is substantially the same as that followed in the second edition of Rammelsberg's work. The statements of localities are generally on a level with the most recent discoveries. The only mineral of commercial importance which we miss is bauxite, which certainly does not figure in the index. The illustrations, being printed from the blocks used in Brooke & Miller's work, are excellent, and contribute greatly to the value of the work.

Chemical News.

TEAM AND MACHINERY MANAGEMENT. By M. Powls Bale, M.I.M.E., Assoc. M.I.C.E. London: Crosby, Lockwood & Co., 1884.

This work forms one of Weale's Rudimentary Series published by Messrs Lockwood & Co.—Owing to the great and increasing competition of the present day in every branch of manufacture, it cannot be denied that it becomes increasingly necessary to exercise every economy that will either lessen the cost of production or increase the efficiency of the plant employed. It must be admitted that a considerable loss often arises through inefficiently managed or badly arranged machinery; and this subject is now attracting a considerable amount of attention, with the result that many old manufactories have been remodeled and new ones built and arranged with appliances to reduce manual labor and the cost of production to the lowest possible As a portion of the matter contained in the author's recently published work, Sawmills: their Arrangement and Management, would, with modifications and by the addition of other chapters, be made more or less available to general machinery users, and be issued at a less cost than that work, he has with this object in view especially written some fifty pages, and issued Steam and Machinery Management. The variety of machinery and manufactures being now being taken.

so great, the author has only selected a few kinds; but most of the hints being general, and not arbitrary, they may be modified as circumstances may dictate. What has now been written by the author may be found of some use by those who intend creeting machinery or who have it already in operation.

MISCELLANEOUS.

In the last paper of the session read by Mr. Stayton, C. E., at the Institution of Civil Engineers, the aggregate length of the streets of London was given as 1,966 miles, of which, excluding 248 miles in course of formation, 1,718 miles are thus maintained by various authorities, namely: Macadam, 573 miles; grantie, 280 miles; wood, 53 miles; asphalte, 13½ miles; flints or gravel, 798½ miles. The existing area of wood pavement is 980,533 square yards, and its estimated cost £600,000. Not more than 4.38 per cent. is east of the city or south of the Thames.

A UTOMATIO LIGHTING OF BEACONS.—In America a system of automatic beacon lights has been adopted. Each beacon is furnished with a reservoir of sheet iron, containing gas under a pressure of fifteen atmospheres. The quantity is sufficient to light the beacon for three months; and fresh supplies are periodically delivered by a vessel which conveys the gas from the factory. A clockwork installed in the beacon, turns on, and lights the gas at the hour fixed for this purpose. The experience of several months has served to test this plan and it has proved so far successful. Attendants live on the shore near the beacons, and see if they are working properly.

Professor G. Forbes has made some observations on a magnetized chronometer watch. The watch went slow several minutes a day. He found the rate to vary with the position of the watch with respect to the cardinal points and also in a vertical plane. He traced the variation of rate to magnetization of the balance spring, the bar and the screws. The fact that it varied with position suggested that a magnetized ship's chronometer might be made which would integrate the course and give a mean course. Messrs. E. Dent & Co. had since fitted a gold spring and a platinum iridium balance to the chronometer, and rendered it non-magnetizable.

A SURVEY of the coal lands of the Canadian North-West has just been made under the directions of the Dominion Geological Survey. Approximate estimates of the quantity of coal underlying a square mile of land in Bow and Belly rivers district give in one case 4,900,000 tons, in two cases 5,000,000, and in another 9,000,000 tons. The coal is, in general, exposed on the surface, and there is consequently little labor necessary to the working of the mines. Though no Government surveys have been made in the surrounding districts, coal-bearing strata are known to extend to the north and west of the parts from which coal is now being taken.

VAN NOSTRAND'S

ENGINEERING MAGAZINE.

NO. CXC.—OCTOBER, 1884.—VOL. XXXI.

THE MISSION OF SCIENCE:

AN ORATION DELIVERED AT THE PHILADELPHIA MEETING (SEPT., 1884) OF THE AMERICAN ASSOCIATION FOR ADVANCEMENT OF SCIENCE.

BY VICE-PRESIDENT ROBERT H. THURSTON, Chairman of Section D (Mechanics).

of the confidence which you repose in me, and to assure you of my earnest desire to do what little my opportunities and my powers may permit toward makprofitable, and toward promoting the prosperity of the great association to which we are proud to belong.

We are especially favored, the present year, in having with us members of our great sister society, the British Associa-

Before taking up the subject which I | their visit to the "City of Brotherly Love" have selected as a proper one for discus- one that shall leave in their memories sion in a vice-president's address, on this so many reminiscences of agreeable acoccasion, I desire to give expression to quaintances made, of strong friendships my sense of the great honor which has begun, of open handed and open hearted been conferred upon me in calling me, hospitalities, and of profitable and interfor a third time, to the chair of vice- esting discussions, that they may never president of the American Association forget the cognomen of this noble city. for Advancement of Science, and to pre- If we shall be able to give them but a side at the sessions of the section. In suggestion of the pleasure and the profit taking the position to which your too gained by those of our own number who favorable judgment has called me, it is were so fortunate as to be able to accept my first and most pleasant duty to thank their generous and whole-souled greetyou for this most unequivocal testimony ings at Montreal, we may well be content. We can at least do our best to convince them that the capital of the "Keystone State," the first capital of the United States, is at least as well entitled ing your sessions both pleasant and to the fraternal regard of our British guests as is the beautiful Canadian city from which they are just come.

As time goes on with steady and unvarying sweep toward the efernity of the future, and as our two nations, our one, hardly divided, people, are becoming tion for Advancement of Science, who bound more and more closely by every have come to join us from Montreal, interest, and by all memories of the past, where the meeting of that society has by all the sympathies that are engendered just been held, and where they have in the breasts of members of one race taken part in proceedings of no less im- and of one great family; and as we are portance than interest. It is our pleasant duty to tender to these gentlemen a hearty welcome, and to endeavor to make number of the great cables of steel

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nerves that stretch across the ocean what was then Section A of this associa-which now only nominally separates us, tion, to take the chair, in the absence of and as we find the once seemingly infi- the regularly elected vice-president for nite expanse of that ocean narrowed by that meeting, and performed the pleasant that most wonderful of the products of task of reading an address, prepared by the growth of the science and the him, on the "Endowment of Science." art of mechanics, the modern steam- Before the meeting of 1878, at St. Louis, ship, until the weeks of the past in the regular course of my duties as have become the days of the present; vice-president, and as chairman of the as we are beginning to realize the same section, it became necessary to prefact of the true unity of the human race, pare an address to be delivered before and the duty that lies with us to promote, the association, and the subject then in every one of the thousand ways that chosen was "The Philosophic method of by the principle of intelligent and honor-these addresses, the attention of the asable self-protection, upon which we are sociation was earnestly called to the numberless ways. thinker since the world began. In be-matter, and at least cost to the world. half of the members of this body, I extend the right hand of fellowship to our knowledge systematically organized. I guests, and bid them heartily welcome to then called attention to the facts that it all that we may be able to offer, and to consists of two divisions: knowledge of share with them, at this meeting.

who have honored us with your cheering trolling and correlating these phenomena. presence. It is just two hundred years As then stated, "all science is thus made since, in deference to the enlightened up from the infinite number of facts views of Sir John Cutler, the Chair of which are comprehended in the universe Mechanics was founded in the Royal So-|of the known and the to be-known. ciety of Great Britain. May we not existence is assured by the stability of hope that this Section of Mechanics of all those principles of philosophy which the American Association for Advance- are woven into the connecting chain." ment of Science may prove to be worthy, "The man of science, the philosoin its interest, its fruitfulness, and its pher whose task it is to create and

THE MISSION OF SCIENCE.

so grand an anniversary?

dress on this occasion, "The Mission of a codifier of laws." It was shown that Science," as one peculiarly appropriate to all science has for its foundation the the time and the occasion.

men of science, more than all other men, advancement of Science," or, perhaps can effectually work, that spirit of selfabnegation and philanthropy, regulated vancement of Science. In the first of beginning to see that we must, and ought necessity of increasing the efficiency of to, rely for the amelioration of the count-scientific work, and of making most less evils which are to-day a consequence fruitful the labor of the comparatively of selfish and unintelligent human ac- few workers in this field, in the United tions, this bond becomes strengthened in States, by securing such an endowment We fully realize that of research as is now, fortunately for "in union is strength," and that the our nation, becoming usual in the departfraternal sentiment which we hope that ments of higher education. In the second these meetings are effectively promoting of these discourses, I endeavored to point may be a very important factor in the out what, in my opinion, is the truly solution of a problem—that of the reduc-scientific method of securing the greattion of the sum of evil in the world— est possible results with minimum exwhich has been earnestly studied by every penditure of life, strength, mind and

I defined science, substantially, as phenomena gathered by observation and Gentlemen of the section and friends experiment, and knowledge of laws constimulation of other and greater work, of to advance all human knowledge of the great kingdom of nature, is, therefore, a discoverer of facts, an observer of phenomena, a student of Nature's laws. I have selected the subject of my ad- He is a systematic recorder of facts, and great, the fundamental principle of the Seven years ago, at the Nashville indestructibility of "the two products of meeting, I was called, by the members of creation, matter and force, and the fruit of their union, energy." cluding chemical—vital, mental, and "the all the arts of daily life and work. master power, Omnipotence, which is the urally to a similar division of science into physical, biological and mental sciences. It is with the first of these grand divisions of science, only, that we are concerned.

The scientific method of advancing science was shown to comprehend a systematic collection of all facts and phenomena, as exhibited to the senses in the course of our experience, either by simple observation or by carefully conducted experiment; the systematic arrangement of the knowledge so obtained, and the registration of this knowledge in natural order and relations: the study of such recorded facts of science with the purpose of ascertaining the laws that define their relations; the similar co-ordination of separate collections of such related facts and laws, for the purpose of detecting the character and the mathematical form of the more general laws that may determine the relations of group to group and of science to science; and, finally, the aggregation, if it prove to be possystem comprehending all the phenomena of nature.

are needed several classes of workers, ciency, must be a specialist, and must modern philanthropists. give his time and his thought and his strength mainly to a single line of work. We must have observers, each of whom liar to, his branch. scheme of universal science. we require a still larger and more direct- gathering knowledge and of constructing

The next step ly useful class, the teachers of science in the argument led to the classification and the no less important body of laborof the forces of nature into physical -- in- ers who make application of science in

But all of these classes being organsource and the sustainer of all exist- ized, and all the fields of work open to ences," and this division leads nat- man being assigned to them, each taking his proper division of the great task, progress would be but slow, and, in these days almost at a standstill, but for the aid of still another body of co-laborers, who, without pretending to deep knowledge in any division of science, without possessing talent for research, either in the laboratory or in the study, and unable often to realize all the beauty and all the importance of the mighty work that they are helping on, nevertheless generously devote the fruit of years of toil and the product of enormous activities and energy to the cause. These are those who have given, and who are still generously and likerally giving, material assistance by their splendid contributions to the scientific departments in our colleges and of our technical schools. The endownent of research, which will certainly ere long become an acknowledged and legitimate division of this work, is, after all, as essential an element of the scientific method of advancing science as either of the others. Those who give of sible, of all science into one universal their substance to aid in the promotion of science are entitled to hardly less honor than those who devote life and To accomplish this great work there health and strength to the good work. Those who take part in the endowment each of whom, to secure maximum effi- of research are the truest and greatest of

When we have thus ascertained what is the philosophic method of the advancement of science, and have determined should be fitted by every natural endow- how we may most efficiently carry on the ment for the study of nature, and for work in the true spirit of the "science of the investigation, by direct experiments science-advancement," we may find it to intelligently planned and skillfully con- our advantage to pause, and to ask to ducted, of the natural phenomena which what end is all this labor to be applied. are characteristic of, and, perhaps, pecu- What is the object of directing this enor-We must have phil- mous array of intellectual power into the osophers capable of perceiving and ex-field of scientific inquiry? Having setpressing the relations of the phenomena tled upon the form of the system, and so collected, and of thus revealing to us the details of the mechanism by which the laws of each of the sciences. We this development of science is to be seneed men who can perceive and exhibit cured with greatest ease, accuracy and the relations of the several sciences to rapidity, to what purpose is this great each other, and their positions in the scheme to be applied? What is the use, Finally, and what is the object, of systematically

a great, an elaborate, system having the the individual, of the family and of the ENCE ?"

tion of the welfare, material and spirit- time, giving him the opportunity to assist ual, physical and intellectual, of the his neighbor most effectively in the enhuman race. It has for its purpose and deavor to reach the same ends, and so far its object the improvement, in every imaginable way, directly and indirectly, of duty that comes to him whether in his the mind and the body, the heart and the private or his public relations. It will soul, of every human being. It is charged aid every citizen in his efforts to gain the with the duty of seeking the cause of most that can be secured by the practice every ill to which mankind is subject; of of industry, skill, intelligence and frugalfinding a remedy for every misfortune to ity, to obtain the comfortable independwhich the race is now liable; of amelior- ence that every man hopes to enjoy in ating every misery known to sage or his old age, and the means of carrying savage; of seeking ways of giving to all his children on to a higher plane than every comfort and all healthful luxuries; that upon which he himself entered when of reducing the hours of toil, and offering taking up his life's work. to the relieved laborer intellectual occupations that shall at once take from him endeavor to prosecute this mission, so all temptation to waste his life in indo- far as they relate to the development of lence and dissipation and give him aid in the sciences, have been already summarhis feeble efforts to climb upward into a ized. higher life; of enlightening the world is in itself scientific. Science first obintellectually; of giving it leisure to per-serves, then experiments with a view to fect itself ethically, and to gain those ele-the revelation of new facts and unknown ments of character that are so sadly laws by systematic research, then applies crushed out by the terrible pressure of the power of logic to the construction of our incomplete civilization, sentiments of an organized, complete and exact system honor and justice, feelings of love and of definite knowledge. First she colsympathy, and a spirit of devotion that lects facts and records phenomena, then can only be found highly developed in she seeks to discover and exactly to eneither the simple child of nature, or in unciate the laws controlling them, and the soul that has time, in the midst of a finally produces, by the intelligent use driving world, to reflect, to aspire and to both of induction and deduction, a symgrow. The true mission of science is one metrical and perfect whole. Thus she that extends far beyond the workshop of creates systems of knowledge, and thus its servants; it extends far beyond our she will sometime, we may hope, knit ken, and beyond the range of our mental these several systems into one great allgrasp and farthest view. The great fact embracing system of the universe. that material prosperity is the fruit of science, and that other great truth, that vancement of science is evidently that as mankind is given opportunity for which will yield the greatest returns, it meditation and for culture, the higher is not the fact that we are indebted to attributes of human character are given such philosophic methods for the prodevelopment, are the best indications of duction of the modern sciences. It is a the nature of the real mission of sci- fact which is more significant than surence, and of the correctness of the con- prising that, as Whewell remarks, "art clusion that the use and the aim of scien- has always gone in advance and science tific inquiry are to be sought in the has followed to give the reasons for the region beyond and above the material phenomena discovered and the methods world to which those studies are confound best in art." "Art is the parent, fined.

us in the protection and preservation of science go hand in hand, it has been al-

promotion of science as its sole end and nation; just so far as it aids each mem-What is "The Mission of Sci- ber of the race to attain the alloted term of life, continuous health, and a maxi-The mission of science is the promo- mum of happiness, while, at the same

The methods properly adopted in the It has been seen that the method

But, while this scientific method of adnot the progeny, of science," and, while The Mission of Science will be fulfilled it is true that progress is always most in precisely the degree to which it assists rapid and most satisfactory when art and

most invariably the case that art has struggled painfully and haltingly, and doubtfully onward, in every department, slowly and unsteadily advancing, yet almost always going before science, who should have been her leader, her teacher, and her most powerful supporter. This fact is not to be considered as representing a natural state of things nor as in the slightest degree discouraging. Like every art, science, in each of its departments, has been passing through a period of infancy, during which it knew neither its powers, its object or mission, nor its proper methods of work. It required protection and the aid of art until it should be fully formed and competent to take up its labors and to requite the assistance which had been given it. In the past the arts have led; in the future we shall see science leading and directing every development of the arts. History tells us that bleaching and dyeing were familiar arts before the science of chemistry had a name; the inventor of gunpowder lived before Lavoisier; the mariner's compass pointed the seaman to the pole before magnetism took form as a science; the steam-engine was invented and set at work, substantially in all essential details as we know it to-day, before a science of thermo-dynamics was dreamed of; the telegraph and the telephone, the electric light and the railroad, have made us familiar with marvels greater than those of fiction, and yet have been principally developed, in every instance, by men who had acquired less of scientific knowledge than we demand to-day of every collegebred lad.

But all this is of the past. Science has attained a development, a stature and a power, that gives her the ability to assume her place in the great scheme of civilization. and will lead. The blind, scheming ways of the older inventor will give place to the exact determination, by scientific methods, of the most direct and most efficient way of reaching a defined end, methods now daily practised by the engineer in designing his machinery. Instead of the parent of chemistry, was there born, long, discouraging, and painful, efforts to reach a result which is indistinctly de- interrupted. fined, science will, hereafter, first deter-powder, the more powerful acids, phosmine just what is the end to be sought, phorus, and systematic chemical methods and then will show the direct line to that of investigation, are some of the products end. Uncertainty will give place to cer- of the intellectual activity of that time.

tainty, and wasted work will be reduced to the least possible amount.

The aids to science have been already briefly referred to. They are partly material, partly moral, partly intellectual. In the very infancy of civilization the most efficient aids were tendered freely to science. The rulers of the earliest historic nations gave encouragement to the sciences, such as they were in their day; governments founded universities in the days of the Greeks and the Romans; the greatest minds of those times were led to turn their attention to philosophy, and students in thousands thronged the schools. Aristotle made a rude yet definite beginning in the physical sciences; Alexander endowed research most liberally in the person of his great master; the same great warrior urged upon Nearchus the prosecution of the greatest of his plans of geographical exploration, and gave him means to carry out his schemes; an enormous library at Alexandria furnished the student the then available knowledge of the world; the enormous "museum" in which it was preserved gave an impetus to science that has never been lost; Euclid, Archimedes, Eratosthenes, Hipparchus and Hero, those wonderful men who gave us geometry, taught us the elements of mechanics, the principles of hydrostatics and the lever, founded systematic astronomy and physical geography, put on record the earliest notions of the correct form of the earth and the motions of the moon, catalogued the stars, and measured their angular distances, and who first used and described the germ of the steam engine and a thousand other mechanical inventions, were themselves the product of an enlightened policy.

The Arabians transferred the seat of Hereafter she will direct science to the west, and erected her capital at the shore of the Atlantic. Experimental science there had a new birth, and the wealth of the Saracens, and the intellect of the greatest among the Moors and the Jews, there contributed to the growth of real knowledge. Alchemy, and her progress has never since been Marcus Graecus'

flashes up and this time it appears of an ocean three thousand miles wide, in what is now the home of Euro-almost in less time than is required to pean civilization. commerce leads to maritime discovery; dines at New York, and sups at Washing-Bruno die that science may forever live; six days; one workman, with the assistthe invention of the telescope stimulates ance of machinery, produces more than, astronomical discovery, and the formal a century ago, could a hundred men, dotion of the modern science of the solar ing their best, in the earlier rude ways. and sidereal systems; the magnificent la- We read, in the beam of light, the disbors of Newton illustrate the progress tance and the rate of motion of the of the sciences of physics and mechanics. stars, and learn in the same wonderful Every branch of natural philosophy system of ethereal waves, to determine grows and puts forth branches in turn, the nature of the matter of which those and the idea of the universal dominion stars are composed. Man is turning his of physical laws becomes accepted as a work in the world over to the more exact foundation principle in science, and as and more powerful machines that he has the basis of the operations of the uni-devised and built, and machinery here the broader science of biology, take form grain, and yonder makes for mankind and grow with astonishing rapidity; and, lying facts determined by the now well-limit. Relieved from bodily toil, mangation. Finally, in the later times, in life in which mental activity absorbs its which the last three or four generations have borne a part, science and art have tellectual development of civilization are learned to work together, and have gone on, hand in hand, each aiding the other, art supplying facts, science finding out nature's laws as illustrated in those facts, this is the picture of the growth of sciand both, gradually, and more and more ence which we are to study to obtain an rapidly and fully, revealing the beautiful idea of what shall be its future. Whenand wonderful system upon which the ever and wherever the mind has been set world is constructed, and all its curious free to study and to meditate, to observe operations carried on, while, at the same and to experiment, science has advanced, time, applying useful knowledge, thus ac- and the whole race has felt the benefits quired, in promoting the welfare of the of her labors. human race. Electricity and magnetism, light and heat, and every form of physi-manded the material assistance of accal energy and of active force, have be quired wealth, and has given to the income revealed to man in all their rela tions, and in all their methods of opera-best and most bountiful reward. Whention. Discoveries in physics and chem- ever and wherever, in the future, science istry succeed each other with a rapidity shall have the substantial aid that she that taxes even the specialist who endea- needs to secure permanent and convevors to keep himself informed in regard nient quarters, and to prosecute her to them. into our life with such wonder-work- mankind be accelerated; and this acceling results that every day sees a new task accomplished that, the day be-pleteness with which the scientific method fore, would have been regarded as of promotion of science is adopted. The

Centuries later, and after a period of voice is transmitted a thousand miles, stagnation and darkness, the light again the written word is sent across the bed The extension of write it; the traveler breakfasts at Boston, the awakening of the people by these, to ton on the same day. Ten thousand tons them, startling discoveries, leads to prog- are transported from continent to conress in every direction. Galileo and tinent, over fifty degrees of longitude, in verse. Geology, ethnology, physiology, weaves his cloths, there gathers his other machines, doing its work with a with their growth, come the minor sci-strength that is never over-taxed, and an ences and the enormous mass of under-endurance that is never found to reach a established methods of scientific investi- kind is coming to that condition of social surplus energies, and the material and incarried on together, and with continually accelerated progress.

This is the history of the past, and

This work of science has always devestment so made its highest return, its Mechanical inventions crowd work, then and there will the progress of eration will be in proportion to the comlittle less than miraculous. The human characteristics of stationary periods, ac-

cording to Whewell, are "obscurity of thought, servility, an intolerant disposition, and an enthusiastic temper." Science teaches exactness and clearness of thought and expression, perfect independence of mind, the most absolute tolerance of honestly held and frankly expressed opinion, and a quiet coolness of to yield a correct judgment. The raof work is due very largely to the introduction and extension of these character- his name. istics of the scientific method, and to the kind.

contempt for real knowledge to his disciples, urged upon them the study, exclusame time, himself failing to give to his followers a real system of morals. He accused men of science of reaching vain conclusions, while he was himself lost in the labyrinth of his own indefinite and baseless speculations. Plato followed in the same track, developing splendid ideas with the brightness of primitive imaginaand engineer; yet he, and all of his con-lies, understood the nature and effects of

temporaries, esteemed his discovery of the relation between the volumes of the cylinder and the sphere more highly than that of the method of determining the specific gravity of a solid or the com-position of an alloy, and deemed the quadrature of the parabola a greater achievement than the theory of the lever action and a deliberation, however enthusiastic may be the nature of the enumeration of the sands of the seaindividual, that may be depended upon shore was looked upon as a nobler accomplishment than the invention of the pidity of recent changes in our methods catapult, or of the pump, which, twentyone centuries after his death, still bears

No system of applied science could influence of the scientific spirit upon man- exist among people who had no conception of the true mission of science, and It is only in modern times, and since it was not until many centuries had the old spirit of contempt for art, and of passed that mankind reached such a poreverence for the non-utilitarian element sition in their slow progress toward a in science, has become nearly extin-real civilization, that it became possible guished, and since our systems of edu- to effect that union of science and the cation have begun to include the study arts which is the distinguishing characof physical science, that we have had teristic of the age in which we live. It what is properly called a division of "Ap- was not until the middle of the sixteenth plied Science." In the days of classical century that Copernicus and the modern learning, science was only valued as it system of astronomy became possible; developed a system of purely intellectual Columbus lived but a little earlier; Gilgymnastics; the old Socratic spirit still sur-bert, also, a little later, supplied a basis vives, but is fortunately without influence for the science of magnetism; Galileo apupon our modern life. Socrates rejected plied his genius to the production of the and condemned all physical and mathematic telescope. His first use of the new inical science, and, seeking to impart his own vention was to earn martyrdom by its application to the proof of the truth of the Copernican system, one of the most sively, of ethical philosophy, while, at the splendid of all the achievements of applied science. The revelation of the phases of Venus was one of the facts which marks the conversion of the world from the old Greek methods of scientific thought. It was not until the middle of the fifteenth century that Europe could produce a Leonardo da Vinci, the first of by uniting the power of a great intellect the great mechanics and engineers of modern times. Taking up the work of tion, and awakening noble sentiments applying science where his predecessor, while giving no assistance to his poor Archimedes, had left it, seventeen cenfellow-creatures who desired to conquer turies before, he accomplished an amount the necessary leisure for the enjoyment of work in the application of the physi-Aristotle in physics, and Zeno cal sciences and of the science of mein ethics, employed the scientific method, chanics, that few men in later times have but their achievements were only apprebeen able to approach, and none, probciated in proportion to their inutility. ably, to equal. He revealed the theory Archimedes was the most perfect proto- of the lever, extending the work of Artype, in those days, of the modern physichimedes to the more general case; he cist and mechanician, of the scientific man was acquainted with the laws of hydraufriction, and, to a certain extent, its laws. slow development of rational views, of Stevinus followed da Vinci, and Galileo's the methods of scientific deduction, and treatise on mechanics, which appeared in of the invariably tardy progress from a 1592, and his "dialogues" of 1633, crystallized the knowledge of his time in acknowledge and inaccurate logic, in the cessible and practically available form. Then came Torricelli, and, a little later, plainly visible facts, and of what ultithat greatest of English philosophers mately seem obvious principles, observe and mechanicians, Newton. whose "Principia" has been, from 1686 to the present time, a mine which has richly repaid all the less illustrious workers who have chosen to explore it. This wonderful ment of this theory, it cannot fail to begeometer gave all his mighty intellectual power to the work of usefully applying science. He enunciated the laws of motion, deduced the law of gravitation, proved, by the application of his cumbersome but fruitful methods, the exactness of Kepler's laws, showed their generality, and pointed out the fact that they hold the planets in their orbits, and sway the whole stellar world.

The time of Newton marks the beginning of a grand outburst of energy in the useful application of the sciences. Every art, every industry, every phase of human life, felt its helping hand. Inventions began to appear, to relieve the delv-tion of the facts determined by the exing laborer, in every department of human industry. The arts began to find a scientific basis, and to look to science for aid in their perfection and in their development; the industries began to feel the stimulating effect of scientific discoveries, and of the introduction of scientific methods of application of practical knowledge; Descartes, Newton and Leibnitz advanced mathematics to a point from which only a Hamilton or a Sylveshis contemporaries, only a century before knowledge so acquired, and endeavored our own time, created chemistry; geology had its birth almost within the by thoroughly philosophical methods. ence of "energetics" is hardly yet de-fined, and has not taken its place in the text-books taught in even our schools of Hirn and Leloutre, in France, have simscience.

presence of what are later seen to be the rise and progress of our hardly yet completed theory of that greatest of human inventions—the steam-engine.

Studying the history of the developcome strikingly evident that, throughout, experimental knowledge and practical construction have been constantly in advance of the theory, and that the science of the conversion of heat-energy into mechanical power has, in all stages of this progress, come in simply to confirm general conclusions previously reached by deduction from experience and observation, to give the reasons for well-ascertained facts and phenomena, and often not always promptly or exactly—to define the line of improvement, and the limitations of such advance.

The theory itself began by the correlaperiments of Rumford and Davy, at the beginning of the century, those announced by Joule and Thompson many years later, and the laws developed by Clausius, Rankine, and Thompson, at the middle of the century. But Watt had discovered the facts which have since been found to set limits to the efficiency of the engine, a hundred years ago; Smeaton, in many respects, the greatest mechanical engineer of his time, ter could carry it further; Lavoisier and made practically useful application of the memory of our elder colleagues; the sev- Clark, a generation ago, showed how eral departments of physics have taken the losses first detected by Watt set a definite shape almost within our own definite limit, under the conditions of fashorter memories; the natural sciences miliar practice, to the gain to be secured have come into being since the time of by the expansion of steam; and Cotter-Cuvier and Linnaeus; the greater sci- ill within a few years has shown, by beauscience. We are, in fact, at the very ilarly thrown light upon the phenomena threshold of the true era of applied of "cylinder condensation," and De Freminville has suggested the method of In illustration of the gradual evolution remedy. Yet it is only now that we are and growth of correct theory, and of this beginning to see that the philosophy of

heat-engines is not simply a thermo-dy- development. wastes of heat. detected and weighed in their influence investigate. upon the theory of heat-engines, years

plied mechanics, that which forms the looked for. basis of the work of the engineer—that including the study of the materials of velopment in matters relating to common construction—our knowledge, scientific practice in the useful arts is hardly less

Experimental work may namic theory, and that it involves prob- be said to have commenced in this field lems in physics, and a study of the a century ago, and the labors of Musmethods of conduction and transfer of chenbroeck, of Tredgold, of Barlow and heat without doing work from point to of Hodgkinson, of Fairbairn, and of their point in the engine. We are only now coadjutors of the first half of the century, fearning how to apply to knowledge gained gave to the constructor and to the theoby Isherwood twenty years ago, and by rist the facts which were most essential Hirn and by Clark still earlier, in solv- to their work. But it is only within the ing the problem of maximum efficiency past few years that the conditions modiof the steam-engine. We have only now fying the value of these materials, as apdiscovered that the "curve of efficiency," plied in engineering, have been carefully as I have taken the liberty of calling it, and critically studied by the light of exis not the curve of mean pressure for perimental investigation. The effect of "adiabatic" expansion, as Rankine called heat upon strength and elasticity, the it, for "isentropic" expansion, as Clausius alteration of structure produced by vi-would call it, but that it is a curve of bration, the difference in carrying power very different form and location, and that and in safe loading, due to reversed it is variable with every physical condi-stresses, the modification of the value of tion affecting the working of the expand- steel by alteration of chemical composiing fluid in the engine. We have only tion and by various modes of tempering, now learned that every heat-engine has a the effect of that singular phenomenon, certain "ratio of expansion for maximum the variation of the normal line of elastic efficiency," which marks the limit to gain limits by strain, the persistence of the in economy by expansion, which limit is effect of strain in the production of coldfixed for each engine by the nature of the worked iron and steel, and in the permaexpansion, and the method and extent of nent record of the results of accidents All the facts of this straining structures—all these have been case were apparently as obvious, as easily matters left for the present generation to

It is only to-day that we are beginning ago, as to-day. Even the latest phase of to ascertain the existence of alloys and the current discussion of efficiencies of special modifications of iron and steel heat-engines, that relating to their com- which adapt these metals to special purmercial efficiency, would seem to have poses, and the engineer is only now bebeen as ready for development a general coming accustomed to the writing of tion ago, when first noted by Rankine, as specifications including details of the to-day; yet, what is now known as a composition and character of the matesimple and easily formulated theory has rials to be used in his work. The use of been several decades in growing into manganese steels and bronzes, of the shape, notwithstanding that all the need-ed facts were known, or readily determin-deoxidized alloys, the search for the exact able, at the very beginning of the period location of the alloy of maximum posmarked by its evolution. It is only with-sible value for specified purposes; the in a year or two that it has become pos-continuation of researches in regard to sible to say that the theory of the steam- the effect of prolonged loading of mateengine, as a case in applied mechanics, rials and of structures; these and simihas become so complete that the engineer lar matters are those which are receiving can safely rest upon it in the preparation the attention of the engineer of our day, of his designs, and in his calculations of and are merely the beginnings of a repower, economy, and commercial effi-naissance in applied mechanics which is likely to reveal wonders where they have Even in the lowest department of ap- been least expected and most rarely

But the slow progress of scientific deor general, has been wonderfully slow of remarkable than the difficulty with which

scientific principles, even when well entific methods of experiment led that the minds of the masses. generally recognized than that which as- ning, the art of weaving by machinery, This was shown by Carnot, sixty years ago, and has been considered one of the fundamental principles of thermo dynamics from that time to this. Nevertheless, so rarely is it comprehended by mechanics, and so difficult is it for the average mind to accept this truth, that the most magnificent fallacies of the time are based upon assumptions in direct contradiction of it. The various new "motors" recently brought before the public with the claim of more than possible perfection, have taken hundreds of thousands of dollars, within the past two or three years, from the pockets of credulous and greedy victims. It is not sufficient to declare the principle; the comparison of steam with ether, and of air or gas with carbon-disulphide or chloroform, must be made directly, and the results presented in exact figures, before the unfortunate investor —whose rapaciousness is too often such as to cause him to give ear to the swindler, rather than to the well-informed and disinterested professional to whom he would ordinarily at once go for advice can be induced to withdraw from the dangerous but seductive scheme. It is true that the principle does not as exactly apply to a comparison of efficiencies of machine, and that the vendor of new motors usually seizes upon this point as his vantage ground; but a careful comparison of the several fluids, both as to efficiency of fluid and efficiency of machine, throughout the whole range of temperatures and pressures found practicable in application, such as has recently been made under my direction, shows that the final deduction is substantially the same for all the usually attainable conditions of practice, and, further, that of all the available fluids, steam is, fortunately, the us to consider our methods of education. best.

established and well known among scien- great engineer. James Watt, to the intific and educated men, sink down into vention of the greatest of mechanical Perhaps no civilizing agents, the modern steam-enprinciple in the whole range of physical gine. It is within the life-span of many science is better established and more who are still living that the art of spinserts the maximum efficiency of fluid in the production of the cotton gin, the inheat engines to be a function, simply, of vention of the sewing machine, and a the temperatures of reception and reject thousand other now familiar and essention of heat, and to be absolutely inde- tial factors of our present life, have been pendent of the nature of the working fluid. born of this union of science and art. The locomotive, the steamship, the telegraph, the telephone, are all younger members of the same family—the mighty progeny of that mightier pair. world has learned to value science for her beneficence, for her fruitfulness, for her helpfulness. It has learned that to a true union of science with art only, are we to look for the methods and the means by which mankind is to be finally, if at all, emancipated from the yoke of overburdening labor now so terribly oppressing the race.

The cultivation of science, in its relations to every branch of the arts, and to every department of the industries of the world; the collection of practically important facts, and the discovery of its essential laws, as forming a system of application of science, is, as is now sufficiently evident, the task which lies before every scientific worker. It is further evident that there must be inaugurated a system of cultivation of science that shall promote the advancement of scientific knowledge, and that shall aid in the application of science to the daily work of humanity. We have seen what such a system must be, and how it must be developed and set in operation. In the carrying out of this system of promotion and cultivation of science, we are to see that men of science are given all necessary assistance in their noble task; and the way in which this aid is to be obtained and made effective has been already discussed at sufficient length. But, when this part of our work has been satisfactorily organized and set in operation, we have the no less important task left us to see that the knowledge so acquired shall be preserved and communicated to the new generation. This leads

Glancing back into history, we find It is only since our political body be-that the distinction which I have pointed came a nation that the application of sci- out between the old and the new schools

equally marked in the methods of education of the older civilization and the new. only education that could be obtained in with a small allowance of pure mathe-The languages, history, litermatics. ature, the elementary mathematics, and the old systems of speculative philosophy, were the principal subjects taught in our colleges. Gradually, the natural and physical sciences came in, and were given a subordinate place in the college course, and then only under protest. The stereotyped argument for the retention of the old system, to the exclusion of the new, was, and is to-day, the assertion that the old system strengthened the intellect and broadened the views of the student, while the new subjects were merely use-The fact that the study of science is the most effective of disciplines for the reasoning faculties, for the memory, for the judgment, and for the very faculties for which the older instruction is claimed to do so much, is not even now perceived, far less admitted, by many of our most distinguished and ablest educators. But, in spite of all difficulties arising from ignorance, prejudice, habit and opposing interests, the study of applied sciences is becoming as well established, as part of the modern college course, as is that of any branch of pure science; and the study of pure science is very steadily becoming a more important part of the standard system of general education—of "liberal" education—while, at the same time, it is gradually becoming changed in its form of presentation, to adapt it more perfectly to its subsequent use in applica-Speculation is everywhere losing its place, and investigation and systematic research are advancing to occupy the deserted ground.

The modern method of education is beevery detail of the educational system, and lives. of the whole course of tuition, determining what methods are the most fruitful professional schools from the colleges of of useful and practically valuable results, the country, precisely as they now enter what are the subjects, and what the the medical schools and the schools of

of philosophy and of thought has been the learner the largest amount of permanently retainable and widely applicable knowledge, Our primary education has Only a few decades have passed since the always, and necessarily, been distinguished by the predominance of the scientific methour schools was one embracing merely od and of the practical side. We have not the purely literary and the speculative, been driven so imperatively toward this use of scientific methods, and of application of the sciences bearing upon common life, in the higher education; but the wisdom and the expediency of a modification of old ways, in this respect, is now rapidly becoming acknowledged, and the new education may be considered as fairly and safely introduced. We may call it the modern systematic method, the scientific method, of education. Science will never, we may be sure, displace entirely the older departments of education; but science will henceforth take a place beside them as no less valuable for mental discipline, and as the essential factor in the promotion of progress in all the arts and employments, in all the daily life and work of the world.

And not only may we feel assured that science will never entirely displace the older systems of education, although certain soon to take her rightful place beside literature and philosophy, and her own most efficient servant, mathematics; but we may plainly see that the time is not far distant when we shall have, for those who propose making science their mistress, and for those who are to make the work of their lives the application of science to the arts and the humbler industries of the world, "schools of science in every city, colleges of science in every State," and universities of science, pure and applied, as the base of the great pyramidal educational system. And it may be anticipated that when the system shall have become perfected and of full growth. it will be the universal custom of those proposing to study in these advanced schools, to secure, first, the general education, the broad culture, and the discipcoming thoroughly systematic. It in linar preparatory training, that the acavolves the introduction of scientific meth- demic schools now give, before entering ods of promotion of the efficiency of in- upon the special branches of study that struction; it includes the careful study of are to be continued through their later

Students of science will enter these methods of presentation, which give to law, making their professional studies

themselves wholly to scientific work.

have written "On the Commonwealth." wealth, by defending and sustaining her ful and most beneficent ally, Science, will, purposes, a greater world.

The place of these modern methods in our political and social system can now be readily determined. Had it been asserted a generation ago that science political economist and of every philosowould, have excited a smile, and would neither have received consideration nor that this is precisely the place which will social economy, and of ethics. be ultimately, and of necessity, taken by for intelligent direction.

government is to secure to every member lated to the industries of the world. of the society which it guards protection two great needs of mankind to-day are,

post-graduate courses. The line will thus much wealth and to secure as many of lie through the primary schools. which the comforts and luxuries of this life as are becoming each year better fitted to be may, and opportunity to prepare the give the child the best introduction into coming generation most effectively for a life either of labor or of study, through successfully doing the work that lies bethe higher schools, in which instruction fore it. This is not the object accomis daily becoming more practically valua- plished by the old governments. They ble, both in the imparting of knowledge were established for the purpose of proand in mental discipline, through the colmoting the welfare of ruling individuals, lege, where the discipline already given or of ruling classes, and the result of their will make the student capable of securing control of society was, invariably, the elgood and permanently valuable knowl- evation of the one class at the expense of edge, into the scientific school, and, in the other; the rulers flourished at the many cases, onward and upward into the cost of those who were ruled. Modern university of sciences, in which all science systems of government are continually is specialized for those who propose, as approaching that ideal form in which the every scientific man must, to devote people govern the people, and in which the public good and the security of the Thus, ultimately, will science lead, di-citizen is the end sought. But, as it is rect, and most efficiently aid, the nation the end and aim of every good governin its progress toward the ideal, yet ap-ment to promote the welfare of the citiproachable, social state which has been zen by purely general legislation, and by the hoped for, if not the promised, land the enforcement of laws enacted without of every great political and social econo- reference to individuals or classes, it bemist and philosopher, from the days when comes the duty of the citizen who ap-Cicero thought it his greatest honor to points the legislator, and of the legislator who makes the laws, to seek the scientific, up to the present time. According to the logically and the ethically correct, Cicero, the Roman Commonwealth, "by method of promoting general welfare. It defending its allies," took possession of is here that science, at the very start, bethe world. Our own grander common-comes properly our guide. The government is charged with the duty of guardas yet hardly recognized, but most power- ing and promoting every legitimate industry, of giving every citizen the means some time, control, and for vastly grander of preparing himself to do his work in the world and of developing, in every proper way, the natural resources and the appropriate industries of the territory over which it has control. How this can best be done it is the province of science to should control our politics and dictate in point out. Men of science, each in his every movement of our social system, and own department, are the natural advisers that it should be the guiding star of every of the legislator. Citizens and legislators are both entitled to claim this aid from pher, whatever his province, the claim those who have made the sciences of the several arts their special study, and from those who have devoted their lives to the provoked rejoinder. But we shall see study of the sciences of government, of

Of all the many fields in which the men science, and that it is to science that of science of our day are working, that every great movement, whether political which most nearly concerns us, and that or social, industrial or ethical, must look which is of most essential importance to the people of our time, is that department The object of every correct system of of applied science which is most closely reof life and property, liberty to earn as first, an education that shall enable the

civilized life, a fair share of the comforts, and even some of its luxuries; second, such provision for the non-workers, deserving but invalid, willing but impotent, as shall insure them against actual suffering, and, if possible, give them some compensation, in the short remainder of life, for their misfortunes. By thus reducing the suffering existing in the world, science will accomplish its highest mission. Government has two main objects to secure: the suppression of crime and the promotion of industries. It is in the latter that applied science finds its plainest and its most obvious line of application, and in such application, as we shall readily perceive, the department of science which must find widest and most important fields of application will inevitably be that of "Mechanics."

the world in an astonishingly greater deingly great importance as one of the great strong man, that spins our cotton and are problems that confront the investiour wool, weaves them into cloth, and even cuts the cloth to pattern, and, by its most ingenious of minor applications, the seen just how, a real bearing upon the sewing machine, gives the garment perhim to calculate the elements of the plan-ducting working cylinders for our heatets and the stars, teaches the mariner his engines; the production of the electric system of navigation, gives him the ship are without variation of intensity of in his magnificent work of designing the power with absolute steadiness and unimachinery which impels the enormous formity of speed; the concentration of structure. Even the sister sciences, physics and chemistry, are departments of application of the mechanic's inventive applied mechanics, and are coming to power to the cheapening of all the in a still more comprehensive but younger are obviously within the province of our

workers to acquire all the necessaries of branch of our science—that of "energetics."

> Even vital forces are gradually coming to be grouped under the same head, and all the natural sciences are more and more generally recognized as properly falling into the department of energetics, and as illustrations of the application of the laws of mechanics. The Mission of Science is to be fulfilled mainly, then, through the application of mechanics.

How the application of our beautiful and noble science is to promote the welfare of the race by the solution of the apparently abstract problems which everywhere challenge the student of science may not always be readily perceived. The mechanics of the ether, the determination of the exact measures of its elasticity and density—of which we only know to-day at of "Mechanics." that the one is probably as enormous as Mechanics directs the advancement of the other is inconceivably small—the character of its vibrations, the method of gree than does any other department of distribution of its molecules, their magscience, and it has, therefore, correspond- nitudes and distances, and the extent of their movements; the methods of conagents of civilization. Every industry is version of mechanical energy, or of other largely mechanical; nearly all of the pro- forms of energy, into light and into heat; ducts of the labor of the world are given the great problem of transformation of form, to a greater or less extent, and heat into mechanical energy without usually principally, by mechanism. It is waste; the still greater problem of the applied mechanics that sows and reaps direct transmutation of the work of chemour grain, that grinds our flour, that trans- ical combination into other forms of work ports it to domestic markets, that carries and power; the discovery of the nature it across the ocean to the half-fed people and method of operation of those forces of Europe; it is applied mechanics that which give rise to chemical and electrical prepares our cotton for the mill, that energy; the method of conversion of the compresses the product of acres into a two forms of energy, the one into the bale that may be handled by a single other, with maximum efficiency; all these gator to-day, and all have, directly or indirectly, although it may not be easily prosperity of the race. Those more dimanent form. Applied mechanics gives rectly "practical" problems, such as the to the astronomer his telescope, enables discovery of a means of making non-conthat he thus directs, guides the engineer light; the development of mechanical power for aeronautic applications; the take their place in the wide spreading department of "molecular mechanics," and perishable necessaries of life; all these

science in the prosecution of its benefi- and, to the uninstructed observer, it may powers and of all the affections.

The progress of science, as seen in her daily into more perfect brotherhood. past history, resembles that of the great sults of human intellect, working through the scientific application of mechanics, which to-day mark the advanced position of civilization. In the building of the steamer long weeks are spent in the preparation of plans, in the calculation of proportions, and in the determination of the form in which the enormous masses of iron are to be grouped; months are spent in gathering the materials together which are to be given shape in the great vessel, and which are to be turned and planed and cast and forged into the pieces composing the mighty engines and lesser machinery; during months and months the tremendous structure lies motionless upon the ways, slowly taking shape, slowly receiving the massive ma-

cent mission. But it is not enough that appear utterly improbable that the dorit shall be made possible that one pair mant mass can ever be more than an inof hands shall do the work of two; work ert and useless hulk; yet, after a time, must be found in new fields for the pair when the period of preparation is comof hands thus thrown out, and this makes pleted, and when all that is needed for it the duty of science and of its workers the purposes intended by the designer to see that new departments of skilled and the constructor has been brought toemployment shall be opened to surplus gether and put in place, suitably conlabor. Thus the development of new in- nected, part to part, there comes a time dustries becomes as much a part of the when a change and a movement are perwork of science in the future as is the ceived. A few insignificant pieces of timimprovement of those now existing. The ber are knocked away, and the enormous new industries must evidently be mainly vessel, slowly and by imperceptible accelskilled industries, and must afford emeration, moves down toward the water, ployment to the more intelligent and and, with continually increasing speed, more finely endowed of those to whom finally rushes into the element which is our modern systems of education are of- to be, for all its future life, its home. A fering their best gifts. When this pro- halt and a little more delay, and the now cess of industrial revolution shall have fully equipped and self-impelling steambeen effected, the great mass of mankind ship once more moves. Starting again, will be able to secure by the labor of each with slow and hardly visible motion, by day, restricted to such number of work- the exertion of her own unseen, but ining hours as shall best develop and conceivable power, the great ship gradumaintain in healthy condition the whole ally acquires velocity, and we see her, muscular system, all the necessaries and later, traversing the ocean, back and comforts of civilized life, and will yet find forth, over a thousand leagues of water, time for recreation and for the cultivation like an enormous shuttle, weaving bands of the moral and intellectual faculties, that tie closer and closer hitherto separand for the development of all the mental ated members of a common race, of one human stock, and binding the nations

So it was with science in the past, and steamships which are now the embodi-ment of the most wonderful of the re-in the earliest historic period, was her time of slow and unobserved generation and embryonic growth. All through the middle ages signs were not wanting of her existence and gradual development, in the changing methods of thought of mankind, and in the accumulation of materials to be usefully applied at a later date. At the beginning of the seventeenth century, the first great movement began, and then only did the true purpose of all that earlier period of preparation become evident. A century ago, with the birth of the steam-engine, later, with the introduction of product of the printing press into the daily life of the world, with the apparition of the electric telegraph and the introduction of the railroad, began the real progress of science, and we are chinery which is to form the vital appar- now seeing but the beginning of her aweatus essential to the life-like action of that inspiring career. She has taught us to powerful, and hardly less than living, creadrive ten thousand tons across the seas, ture; no sign of life or power is seen regardless of wind and waves, by the during this long period of development, might of our 12,000 horse-power engines

—engines in which steam does more work result in the production of a race of men than fifty thousand actual horses could peculiarly adapted to such environment and across the continents, girdling the science, such tasks as lie before him to shown us how to drive the railway train, and living freight, faster than bird can news of every land, gathered in every this scientific development, and the nofor his own comfort and for the care and power of production to that of consumpare governed by the people, for the best | Mission of Science? good of the people, and in which legislathe protection and support of the indus- way by the uncertain, but always increas-

and her highest work will be found to the rippling waves stirred by the first include, I think, important modifications gentle breezes of the dawn, the flashing of the methods of evolution and of con- of a broad band of glory, each wave at life must inevitably, as it seems to me, ful of the beautiful light, each passing it

do, continuously. She has taught us to as science is rapidly producing. Thus send printed messages across the oceans accomplishing, under the guidance of our world with her mysterious wire; she has accomplish, the "Coming Man," with his greater frontal development, his increased with its hundreds of tons of merchandise mental and nerve power, his growing endurance and probably lengthening life, fly; she has helped us give to the people will be the greatest of the products of clime, and brought to us by messengers blest of all these wonderful works. And swifter than the shadows of the sun, and may it not be possible in the better days printed on millions of sheets between the of that future into which we may now first glowing of the dawn and the rising of the orb of which Aurora is the messen-increase of the population of the world ger; she has given practical expression to shall be limited, not as now by the maxia myriad of other hardly less magnificent mum of misery and suffering bearable by philanthrophies. Yet the mission of science the race, nor yet by art, not by a Malhas made but the veriest beginning. It thusian system, but by the rate of expenstill remains to her to perfect and to sys-diture of vital power in the operations of tematize a thousand new industries, to the mind, of the intellect, and of the afinvent as yet unimagined new arts, to fections, when those who are brought into bring the laborer worthy of his hire all the world shall have fair prospect of bethat he needs, and all that he can desire ing permitted to lead happy and prosperous lives, when suffering and misery shall comfort of his family, to so adjust the have been reduced to a minimum—that we may see man taking the place assigned tion, and both to the working capacity of him by Ruskin? Says that great master the world, that the now seeming natural of expression: "All the power of nature conflict between the employer and the em- depends upon subjection to the human ployee, between labor and capital—that soul. Man is the sun of the world; fallacy which is the support of every dem- more than the real sun. The fire of his agogue—shall no longer have even the wonderful heart is the only light and appearance of existence. She has still to heat worth gauge or measure. Where he do her part toward the reduction of all is are the tropics; where he is not, the systems of government to the one only ice-world." May not this development of correct form; that in which the people the human soul be, after all, the true

As a toil-worn traveler, wearily faring tion is solely directed toward the protech omeward at early dawn, skirts the westtion of life, of liberty to do right, toward ern shore of some broad lake, picking his tries of the country, the sustaining of a ing, light penetrating the cloud beflecked system of education that shall give to sky, at last sees in the east the uprising every citizen the opportunity to fit him-sun, and watches its steadily growing self with maximum efficiency for the du-disk, and the wide-extended sheaves and ties of a well planned life, and the encour- pencils of splendent golden light, silveragement, in every right and reasonable ing and gilding, and magnificently tintway, of all that tends to aid the material ing, every snowy pile of vapor, etherialand the moral welfare of the community, izing all the low-lying mist that hides the She has all this and much more to do; bosom of the lake, and sees finally, across formation of the race. The enormous the distant shore catching up its share of advancement of the intellectual side of the wonderful illumination, each its handhopeful, and happy.

onward to the nearer swell, and each had lasted for centuries; and, as the catching new beauty from the passing bright luminary that is to guide him beams of the day-god, until the eyes are through all the future, has arisen, steaddazzled by the spreading sheen, and all ily and constantly, among the obscuring, the scene is surcharged with light, until but breaking, clouds of the dark ages, the the glory covers the weary one, lighten- mists have been dispelled, the clouds ing his heart, cheering his soul, quicken-themselves have received golden and siling his step, and sending him homeward, ver linings, and the all-pervading with all his sadness gone, refreshed, beams, caught and reflected, but always advancing, have finally reached So Man, plodding onward, sad, over- the hither shore, and Man, enlightened burdened, and despairing, toiling wearily and strengthened, with new insight into over the shifting sands of life, at last has a brightening life, himself advances, with seen, across the expanse of eternity, along new courage and renewed hope, toward the shores of which he wanders, the first that future which it is the heaven-directed bright beams of the light of Science, her- Mission of Science to illumine with the alded, but hidden, through a dawn that radiance of ever-increasing knowledge.

CHINESE IRON FOUNDRIES AND RICE PAN CASTINGS.

From "The Chemical News."

colony of Hongkong. China. The previously mentioned town which compartment a piston works; the

Although the Chinese, as a race, are of Sam-tiu-chuk is inhabited principally incapable of the deep thought and ex- by Hakkas, and is one of the principal treme mental effort required to elaborate towns of the sparsely populated and the intricate details of modern scientific mountainous district of Kwei-shin. The machinery, or to plan those bold enterior iron used is obtained by smelting the prises and extensive systems of road and magnetic oxide, which is found in large hydraulic engineering which are the pride masses in the mountains surrounding and glory of the British civil engineer, the town. The ore is broken up, and yet, per contra, it must be conceded that smelted with charcoal in a primitive for finnicking, tedious, patient ingenuity smelting furnace or cupola some eight of a certain sort, the Chinaman stands feet high; the cupola is cone shaped, almost without a rival. As a notable having its apex, or smaller diameter, at example of this same patient, plodding the bottom; the single tuyere pipe is of ingenuity, shown by the Chinaman in earthenware, the opening for emission some of his trades and industries, may be of the blast being placed downwards. instanced the manufacture of the very The furnace itself is of earthenware, or thin cast-iron rice pans which may be rather puddled and dried clay, kept from seen in almost any cook-house in the falling to pieces and strengthened by The principle hoops and longitudinal straps of iron; the seats of this industry are at the towns whole is lined with clay several inches of Sam tiu-chuk, in the Kwei-shin district thick; the internal diameter at the botof the Wei-chow prefecture, and at the tom may be about two feet, or perhaps a busy, populous, manufacturing town of little more, and at the top about three Fatshan, situated in the Nam-hoi district feet and a-half, inside depth about six of the Kwang-chow prefecture. This feet. The blast is produced by a rude latter town is distant but some twelve yet most ingeniously contrived bellows, miles, in a south-westerly direction, from formed of a wooden box some five feet the provincial capital of Canton, and has, long by three feet in horizontal and a from the extent and importance of its foot and a-half in vertical section. This trade and manufactures, notably its great box is divided longitudinally into two trade in iron goods, tools, and hardware, compartments, each eighteen inches been aptly termed the Birmingham of square in vertical section, in each of

valves are so arranged that one piston is thirds the thickness of the mould; these effective in the up, the other in the down, or rather return stroke, for the machine is arranged horizontally. It will be seen, perfectly continuous, there being a slight cessation at the end of each stroke before the return stroke can be effective. The fuel used is charcoal, and the furnace, being first heated by starting a fire with fuel alone, is then filled up with alternate layers of charcoal and ore in small frag-The blast is urged, and after a sufficient time has elapsed, the molten metal is drawn off from a tap hole at the bottom in the usual manner, and cast into ingots, which, when intended for export, are afterwards reheated in an made from genuine native iron, fetch a dollars per picul, or even more, being Fatshan iron, which, to a great extent, West River), is smelted from hematite into the moulds. able extent with gangue, rarely pure, and of varying and uncertain chemical ually. composition. The iron smelted from this latter ore, although far more valuable in the native estimation than foreign imported iron, yet does not realize so high a price in the market as the other.

For making the very thin rice pans, which are cast without handles, pure native iron alone can be used; as being smelted with charcoal, it has the property, when melted, of being more fluid than the luting attaching the upper portion iron smelted with coal; or it may be that the iron itself, being uncontaminated with sulphur, or phosphorus, possesses the property of greater fluidity on this account. The moulds in which the pans are cast require weeks of tedious and patient labor to bring them to perfecan upper and a lower-and are made of less size, which, from the extreme thincarefully puddled clay, the upper portion ness of the pans, making them but little about an inch and a half, and the lower less brittle than earthenware, requires the somewhat thicker; the lower or under greatest care in its removal; these runhalf is full of round holes, about half an ners are carefully sawn off, the use of the inch in diameter, which pierce about two-more expeditious cold chisel being more

holes are made in order to allow the clay to dry thoroughly; the moulds are turned true on a revolving potter's table however, from this arrangement, as there of the usual pattern, and when quite dry is no air chamber, that the blast is not receive a final coating of fine moulding sand, and are made perfectly smooth. The two portions of the mould are then luted together with clay and placed in a large round oven some six feet or more in diameter. The pans are cast bottom upwards, each mould having a runner but no riser; the upper portion of the mould has three little legs in order to support it when drying previously to the two moulds being luted together. After being placed in the oven, which is some two and a half feet deep, the moulds are surrounded with charcoal, which is fired, open forge, and beaten into blooms of and the ovens closely covered with a cuabout six pounds in weight; these may riously constructed earthenware, or rather occasionally be seen for sale in the iron-dried clay cover, kept together, as in the dealers' shops in Hong-Kong, and, when case of the furnaces or cupolas previously mentioned, with bands and straps of iron. very high price, indeed, as much as four The process is so timed, that by the time the moulds are at a bright red heat, or sometimes paid for the best quality made almost white heat, the iron in the cupola from the black or magnetic oxide. The is melted, and ready for tapping; the molten metal is then run out into ladles comes from Ying-tak (a town on the made for the purpose, and quickly poured When these are all (the red oxide), but mixed to a consider-filled, the cover of the oven is readjusted, and the whole left to anneal or cool grad-

The great secret about this process, which enables the Chinese founders to cast their iron pans of such large diameter, yet so thin and light as to be scarcely thicker than a sheet of paper, appears to be the use of highly heated moulds, and pure iron smelted with charcoal. When the ovens and their contents are cooled down, which takes about two days, of the mould to the lower is carefully removed, and the moulds being separated, the pan can be extracted: when the operation has been successful the same mould can, with a little touching The pans up, be used several times. now have each attached to its bottom a They are composed of two parts—runner, or lump of iron, of greater or

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handles.

fire-wood is required to heat them proved itself to be.

likely to cause fracture than the slower through. The manufacture of iron rice but steadier saw; the edges are smoothed pans is in Kwangtung province a Chidown, and the pan is ready for the export nese Government monopoly, which is market. Handles are attached to these farmed out by the Salt Commissioner, pans by the retail dealers, who bore holes and by him licenses are granted to the near the rim of the pan, and attach local iron founders on payment of a small ribbons of iron for the purpose of heavy fee. Considerable care has to be used in packing the pans for export, in order to prevent breakage, which, how-The pans made at Fatshan differ from ever frequently occurs when any considthe preceding in being cast with handles attached near the rim to the inner sur-Australia or other distant ports. An atface of the pan, which necessitates the tempt was made, some years back, to breaking of the mould at each casting, it cast rice pans in Hongkong, but the lobeing rare for the same mould to be ser- cality chosen, Shau-ki-wan, being an unviceable a second time. The Fatshan healthy one, many of the workmen died, pans are also usually cast much thicker others left the place sickly and fever and heavier than those of Sam-tiu-chuk, stricken, and the concern from this cause and occasionally as large a proportion as mainly proved a failure. It may, howone-third of foreign cast iron, generally ever, be possible that had a longer time, Kentledge or ordinary pig iron, is mixed say a year or more, been allowed to elapse with the native iron for casting. In for the newly filled-in ground to settle other respects the process followed at down, and the freshly cut hill side adjaboth places is the same. The Fatshan cent to finish giving off its malarious pans being thicker are the more durable exhalations, the place would not have of the two, while the thinner Kwei-shin been so unhealthy, and in that case the pans are more popular with poor people, result might not have been so disastrous because being thinner a less quantity of to all concerned, as it unfortunately

ON THE PRACTICAL RESULTS OBTAINED FROM VARIOUS WATER-RAISING MACHINES IN HOLLAND.

By G. CUPPARI.

From Selected Papers of the Institution of Civil Engineers.

Author visited Holland, and spent a year the engines. and a-half in studying the hydraulic works in that country, particularly those for draining land. Having had opportunities of examining the principal works, both finished and under construction, and of taking notes from various documents referring to them, he collected a large amount of information not otherwise procurable.

H. P. per hour. In practice, however, lows:—

Towards the end of the year 1877 the there are great differences in the duty of

The Rhineland Company. Pumping Station at Halfweg.—This station was erected for the purpose of discharging into the Y (which was converted into a canal in 1873) the waters of the general collecting basin of the great Rhineland Company. The surface of this basin (called "boezem," a Dutch word which will be used throughout the Paper) covers 8,600 acres, when the water is standing at its normal level. There discharge In the specifications for water-raising into this basin, naturally, the high lands, machines in Holland, a clause is inserted 30,443 acres in extent; artificially, the to the effect that the consumption of polder lands. These are classified accord-Ruhr coal is not to exceed 6.61 lbs. per ing to the normal water-levels as fol-

Acres. Normal level at 3.28 feet-AP and over.16,282 bet. 3.28 ft. and 5.0 ft.-AP.60,855 " 5.0 6.522,314" 6.5 46 44 11.5 " 11.5 66 66 13.1 3,249 " 13.1 66 " 14.753,874 " 14.75 66 44 66 16.4 66,029 66 66 " 16.4 18.0 6,731 66 " 18.0 66 19.7 66 7,882

These areas vary year by year in Holland, owing to the increased drying up of the land, the variations in the normal The above are the figures for level, &c. 1867, since which date there have been no changes of importance. The total area of Rhineland is 258,382 acres, but it also receives into its boezem the waters of the Woerden Association, of which the boezem area is 403 acres, and the total area draining into the boezem of Rhine-

land is 302,590 acres.

When the lake of Haarlem, which was in communication with the boezem of Rhineland, was drained the great diminution in the receiving basin was compensated by providing a better outlet into the North Sea at Katwijk, and three pumping-stations, at Halfweg and Spaarndam on the Y, and at Gouda on the Yssel. In 1880 another was added at Katwijk. The waters discharging into this receiving basin, composed of a network of canals and small lakes, come for the most part from the polders, that is to say, the discharge is performed mechanically. this first lift is generally insufficient, and a second is required, which is effected by steam pumping-engines.*

The internal conditions of the boezems

are,

Mean	water-leve	d (1873-7).	1.656	feet-AP.
Minimu	m "	" " .	2.297	6.6
Maximu	ım ''	"	0.656	6.6
The ma	ximum sho	ould be	1312	4.6

The levels of the Y previous to its canalization were at Halfweg,

	Feet.
Mean high water	0.26 + AP.
" low "	
Maximum high water.	$\dots 6.62 + AP.$
Minimum low "	

After the closing of the Y, the canal which took its place was to be maintained in terms of the concession at 1.64—AP.

This level remains simply a desideratum as far as Rhineland is concerned, while during the past year the mean level of the canal at Halfweg was 1.20—AP. The last pumping station was intended to control the internal levels, in which the difference of a few inches might cause incalculable damage; the maximum ought never to exceed 1.31 ft.—AP.

The Halfweg pumping station has six float-wheels, of a combined width of breast of 38.70 ft. The external diameter of one of the wheels is 23 ft., that of the other five, 21.33 ft.; the internal The floats, twenty-four radius is 5.92 ft. in number, are inclined to the radius, so as to be tangential to a circle concentric with the wheel, and having a radius of 2.85 ft.; the center of the wheel is at 5.6 ft. + AP. The steam-engine has four separate valves, with expansion regulated by hand (of the old double-acting Cornish type); the cylinder is 3.33 ft. $\times 8.0$ ft. There are three boilers always in steam, having each 538 square feet of heating The maximum pressure is three atmospheres. The driving axle is connected by toothed gearing on each side to a shaft carrying three wheels; the speed is reduced in the ratio of 13.5 to 6; the wheels are all upon the same shaft, but this is not all in one piece, but in several, which can be coupled up as re-

There are three systems of construction of water-wheels, which differ in the method of transmitting the force. In the first system the force is transmitted by a driving axle and spokes acting as struts; in the second by a toothed wheel upon the circumference, the axle and spokes acting as struts; in the third, by a similar toothed wheel, but with a double set of rods in tension instead of spokes. The Dutch still adhere to the first system, although, according to Redtenbacher, it is not suitable when the power exceeds 10 or 12 H.P. With large wheels it is very heavy; thus, the Italian wheels at Bresega, near Adria, which are on the the third system, have an external diameter of 39.4 ft., an internal diameter of 26.25 ft., and a breadth of 6.56 ft.; there are no larger wheels than these either in Holland or Italy. The displacement of water is about 5.300 cubic feet per minute per wheel. The axle of these wheels has a diameter at the thickest

^{*}In 1881, there were discharged from the boezem 21,825 millions of cubic feet of water, of which 12,337 millions were raised by machinery; 2,634 millions cubic feet were let into the boezem, the greater part in summer to supply the canals.

part of 1.41 foot, and 1.25 foot at the creases with the lift. When the lift was bearings. The wheels at Katwijk, which from 8 inches to 1 foot, the consumption are on the first system, are only 29.5 ft. of coal per HP. per hour averaged 14.20 in diameter, yet the axles of the furthest lbs.; when the lift was from 1 foot to 1

1 ft. 6 in. in diameter, and weigh over 6 per hour. tons; each wheel has four sets of spokes, axles nearest the motor weigh nearly to drive the wheels themselves. amounting to 7,063 cubic feet per minute performance of the engines when simply per wheel, seems small. The velocity of the turning the wheels, but, failing such exsystem to bending only.

wheels with curved buckets capable of low-water side. Applying the recognized raising water to $\frac{4}{5}$ of the radius, giving coefficient for similar wheels of 0.90, the wheels, one at each side of the wheel, he puts one toothed wheel in the middle, effect was therefore 25 HP. The total expense of two cogged wheels of precisely similar pattern on the one hand, and

15 tons.

the wheel on the other.

of hours worked, the volume of water effect in water raised was about forty-raised, the lift, the effective HP., the three times as great. consumption of coal in each month, and

wheels are of the same diameter as above. foot 4 inches the consumption averaged At Zeeburg, near Amsterdam, there 11 lbs.; when the lift was from 1 foot 4 are eight wheels of the most recent inches to 1 foot 8 inches, the consumpconstruction, of 26 ft. 3 in. diameter, and tion averaged 8.8 lbs., and when the lift 10 ft. 8 in. breast. The driving axles of was from 2 feet to 2 feet 3½ inches, the the wheels furthest from the motor are consumption averaged 5.5 lbs. per HP.

This difference is accounted for by the each set weighing 4 tons; the driving large amount of power required simply double; there are 282 cubic feet of oak, being a constant quantity, is much greatand 222 cubic feet of pine timber in each er in proportion when the work expended wheel. Compared to the mass and weight in raising the water is small. It would of material, the volume of water raised, be useful to have experiments on the periphery is about 208 feet per minute, periments, the author gives instances in which in Holland is considered moderate, which the lift was very small. On the but in Italy high. In this system of con- 16th of March, 1876, with a lift of only struction the axle is subject both to 0.45 of a foot, all the six wheels were at bending and torsion; in the suspension work for 495 minutes, and made 2,043 revolutions, the immersion of the wheels Mr. Zangirolami, of Adria, constructs at the time being 3.75 feet on the excellent results. Instead of two toothed volume of water raised was estimated at thus avoiding the practical difficulty and consumption of coal was 10,493 lbs., or 50 lbs. per effective HP. per hour.

General Delprat investigated experithe twisting effect produced by a single mentally the working of a somewhat simcogged wheel when placed at one end of ilar establishment with six paddle-wheels for eighty days, with lifts varying from At Halfweg the driving-axle is of cast- 0.033 of a foot to 1.75 foot. He found iron, solid, I foot 2 inches in diameter that the useful effect, when the lift was a near the motor, and 10 inches at the furminimum, was only 3 HP., while the ther end, with enlargements at the joints. work corresponding to the vis viva of The framework of each wheel is formed the water issuing from the wheel was 69of three sets of spokes, which are east in .24 HP. With the maximum lift, on the one piece with the nave and ring, or other hand, the former was 130.05 HP., rather each set is cast in two parts and the latter only 19.57 HP. The sum of bolted together. The whole weight of the two kinds of work, useful effect, and one wheel with its axle is probably about work corresponding to the velocity, was 72.24 HP., with the lift of 0.033 of a foot, Tables are given of the work performed and 149.62 with the lift of 1.75 foot. by the wheels monthly during the years This sum rather more than doubled, while 1872-5. The first table gives the number the lift in the last case was fifty-three of revolutions per minute, the number times that in the first, and the useful

These wheels, therefore, besides being per HP. per hour. The second table very costly, have the disadvantage that, shows how the duty of the engine in- as the inner water-level diminishes the discharge also diminishes, while the num- feet. ber of revolutions remains constant. If, then, this reduction in the inner waterlevel is accompanied with a reduction of the lift, the conditions of useful effect are still worse. The six wheels at Halfweg, which with an inner water-level of 8 inches—AP (the highest), give a discharge of 8,263 cubic feet per revolution, give only 5,510 when the water is at its lowest level of 2.46 feet -AP.

Hydraulic Station at Katwijk.—This was erected in 1880 to regulate more completely the waters of the Boezem. The levels of the external water are:—

	Feet.
Mean high water	2 93+AP.
" low "	2.72-AP.
Maximum high water	
Minimum low "	$6.56 - AP$.

The distance of the buildings from the sea is 2,000 feet.

This station and that at Zeeburg, near Amsterdam, intended for changing the water in the canals in that city, are the two largest of recent construction in Holland. In both the system adopted is similar to that at Halfweg. At Katwijk there are six wheels, each 29 feet 6 inches in external diameter, and 8 feet breast. The centers of the wheels are at 8 feet 3 inches above AP., the sill of the channel is at 1.64 foot—AP., which is the mean level of the surface of the internal water. The number of wheels at work can be regulated by gearing. The weight of a single wheel with its axle is estimated at 411 tons. The selection of this system shows that it is considered the one best adapted to the conditions at Katwijk. Flat buckets have been adopted as being the best under the conditions, namely, a lift varying daily (with respect to sealevel), and averaging from 0 to 4.5 feet, with an ordinary maximum of 6.89; the fluctuation of the internal level being very slight, the greatest difference in the year 1881 being 1.60 foot, and the greatest in a month being 0.82 foot. There is no doubt that the differences will be still smaller with the new lifting wheels at able features in the Dutch system.

The effect of this is that with the internal water at its mean level, and the external at mean high-water level, the angle of ingress is about 20° 30′, and that of egress 42°. The proper diameter of this tangential circumference is a subject much discussed among Dutch engineers. This, together with the radius of the wheel, and the position of the axis, determines the angles of ingress and egress, upon which the effect of the wheel greatly depends. Inspector J. A. Beijerinck, the celebrated engineer of the Zuidplas and Haarlem reclamations, and the author of the first really practical project for reclaiming the Zuider Zee, has devoted considerable attention to float-wheels and screw-elevators in a monograph on the Zuidplas, which will be referred to later on. He upholds the rule that the angles of ingress and egress of the paddles with the mean internal and external water-levels should be equal; which, when the radius of the wheel is known, readily gives that of the circumference to which the paddles are tangential, by means of a simple geometrical construction. has long been a general practical rule, and is still frequently followed, though the desire for innovation has given rise to others, perhaps too many.

If a is the angle of ingress, β that of egress, H_i H_e the depths below the axis of the wheel of the internal and external levels, \(\Delta \) the lift, R the radius of the wheel, ρ that of the above-named circumference, we have

$$\begin{aligned} \mathbf{H}_{i} &= \mathbf{R} \left(\sin \alpha \sqrt{1 - \frac{\rho^{2}}{\mathbf{R}^{2}}} + \cos \alpha \frac{\rho}{\mathbf{R}} \right) \\ \mathbf{H}_{e} &= \mathbf{R} \left(\sin \beta \sqrt{1 - \frac{\rho^{2}}{\mathbf{R}^{2}}} - \cos \beta \frac{\rho}{\mathbf{R}} \right) \\ \Delta &= \sqrt{\mathbf{R}^{2} - \rho^{2}} \left(\sin \alpha - \sin \beta \right) \\ &+ \rho \left(\cos \alpha + \cos \beta \right). \end{aligned}$$

Of the quantities H_i , H_e , R, α , β , ρ , any three can be found when the other three are known, according to the theory of hydraulic wheels, by equations which correspond to the minimum for the loss of work due to various causes. This loss work. The manner in which the varia- being expressed in terms of the remaining tions in internal water-level are kept with independent variables, including in these in very small limits is one of the remark- the velocity, which is another very important element, there will be enough equa-The buckets of the wheels at Katwijk tions to determine all the unknown qualiare tangential to a circle concentric with ties. In practice they are given by rules. the wheel, and having a radius of 5.25 One is that already given, from which $\Delta = 2\rho \cos \alpha$. Some authorities make it a rule that the value of α shall lie between 20° and 30°. Since, if the immersion i of the buckets is known, $R = H_i + i$, the value of R depends upon that of i, which is generally beetwen 3.25 feet, and 4.87 feet, according to the difficulties of foundations and construction. Some maintain

ations and construction. Some maintain that the ratio $\frac{\rho}{R}$ must lie between $\frac{1}{3.5}$ and $\frac{1}{4}$. Others state that H_e must lie between $\frac{1}{4}$ and $\frac{1}{5}$ of R, but the principal rule, and that most generally adopted is that of the equality of a and β . At Katwijk, however, this rule has not been adopted. At the maximum daily level the angle of egress is nearly double that of ingress, which is 20° 30'. At the mean level it is more favorable, increasing by about 6° . There seems very good reason for departing from the established rule.

It is true, indeed, that by improving the ingress the egress suffers, but in a very different degree. R being given, a and β can be expressed by a single variable, the angle Φ of the paddle with the radius. The loss at the ingress will be a certain function f_i (Φ), that at the egress f_e (Φ), indicating by f_i and f two different functions. The variable Φ will be determined by the condition that f_i (Φ) $+f_e(\Phi)$ shall be a minimum. It would be difficult and almost useless to determine mathematically the expression of that sum as a function of (Φ) . It is certain that for a given variation of Φ the gain on one hand is very different from the loss on the other, and that it is better to increase the angle of egress. If this is too small, there is a useless heaping up at the discharge, which may be a very considerable part of the lift, or may even exceed it, and the rule of equal angles often places the wheels under unfavorable conditions.

The Katwijk wheels are driven by two compound engines supplied with steam from eight Lancashire boilers, with double fire-boxes, each 32.8 feet × 7.31 feet, with seven Galloway tubes. The heating-surface of each boiler is 970 square feet. It was specified that with a working pressure of 5 atmospheres the eight wheels should raise—

4,238,000 cubic feet per hour with a lift of 4.10 3,532,000 " " " 5.27 2,825,000 " " " 6.88

so that the maximum useful effect should be 615 H.P.

On the trial of the engines, the number of revolutions varied from 3.93 to 4.54 per minute. The most convenient for ordinary working is 4, corresponding to 36 revolutions of the fly-wheel, the velocity at the periphery being 7.22 feet per second. The ratio of useful effect to indicated power varied from 33 to 70 per cent., the average being 50. It is expected that a higher value will be obtained after the engines have been in use a little while, and the gearing has become eased.

The principal dimensions of the build-

ings are:

11150 010.			
	Ft.	Ins. Ft.	Ins.
Engine-house, inside	59	0×49	3
Boiler " " …			
Each of the covered chambers for			
the wheels	44	9×39	4
There are two chmneys 85 ft. high			
above the fire-grates, with an in-			
ternal diameter of	6	3	
Coal-store			9

The cost of the establishment, exclusive of earthwork in the canals, was

For the	buildings, machinery		
	Total	 . 4	229,300

Pumping Station at Gouda.—The external water-levels (of the Yssel) are—

	Feet.
Mean high water	3.64 + AP.
" low "	0.55-AP.
Maximum high water	
Minimum low "	4 26 - AP

When the station was established, in 1857, six paddle-wheels were erected, which in 1872 were changed to wheelpumps, of which the axis was at 7.21 feet +AP, the lowest part of the drum at 2.50—AP, that of the buckets 5.78 feet -AP.The total available width of breast was 31.17 feet. In 1873 two of the buckets, of which there were only six, broke, and in repairing them the number was increased to twelve. the direction of Professor Henket the buckets were made of a curved form, with the concavity towards the inner water. Since then repairs have been effected by Mr. Rijk, who introduced curves with the concavity towards the outer water, the curvature being that of a logarithmic spiral. At one time three varieties of buckets were in use at the same time on 6.88 these wheels, three having Mr. Rijk's form, one that of Professor Henket, two nearly flat. It was evident that the difference in the delivery was slight; Rijk's system was on the whole preferable.

The steam-engine here is of the same class as that at Halfweg. The cylinder is 3.65 feet × 8 feet. There are three Cornish boilers, each having 883 square feet of heating surface. A table is given showing the performance of the engines during the year 1877, from which it appears that, omitting the months of January, April, and May, when very little work was done, and the lift was small, the consumption of coal was 8.6 lbs. per HP. per hour. Under the same circumstances the Halfweg engines and wheels would have given much better results. In the calculation, the loss of water by slipping and by the partial filling of the buckets, was taken at 15 per cent., which is too little. Some experiments gave 22 per cent. for this loss.

General Association of Delfland.—The total area of Delfland, which ranks next in importance to Rhineland, is over 74,000 acres. Its boezem* is relatively very small, about 954 acres. Its conditions in regard to drainage have always been, and still are, worse than those of Rhineland. Besides the small area of the boezem, the natural discharge into the rivers is attended with difficulty, and there was no artificial means of discharge until 1864, when a station was established at Vijf-

sluizen, upon the Meuse, not far from Schiedam.

The levels are as follows, referred to the Delfland datum, D. P., which corresponds to 1.071 foot below AP.:—

Internal w	aters {Minimum	0.82-DP· 0.66+DP·
External	Mean daily high water	$4.00 + DP \cdot0.07 + DP \cdot$
waters	Max. high water, abou	

The water is discharged naturally whenever the levels admit. There are six wheels, disposed symmetrically with respect to the motor, of 26.24 feet external, and 12.47 feet internal diameter. The width of breast is 4.92 feet. They work up to 5.38 + DP. The axis is at 8.35 +DP. The radius of the tangential circle is 2.75 feet. The system of construction is similar to that at Halfweg. The engine has a single cylinder 3 ft. 4 in. $\times 8$ ft. 3 in.; the ratio of transmission is 11: 4.4. The normal velocity of the wheels is 4.4 revolutions per minute. There are three Cornish boilers, 33 ft. \times 6 ft. 6 in.; the maximum pressure is 3 atmospheres.

A serious defect in the action of float-wheels is the great diminution in discharging power as the internal water lowers. At Vijfsluizen, for instance, with the inner water-levels at 0.66—DP, zero, and 0.66+DP, the volumes of water discharged are respectively 1,092, 481, 1,263,133, and 1,421,845 cubic feet, that is to say, that the volume varies from 3 to 4 for the above limits of water-level. The following are the results of two years' working. The year is reckoned from the 1st of May:—

1874–5.—Total number of hours worked, 807. On only thirteen days was water raised continuously during twenty-four hours. The longest stretch of work was 120 hours. The engines were worked so as always to give a useful effect of 104 HP. The consumption of coal was 7.075 lbs. per HP. per hour, including that used for getting up steam and banking the fires while the engines stopped for short periods.

1876-7.—Number of hours in work, 2,086. Continuous work throughout the twenty-four hours on twenty-eight days. Consumption of coal 6.90 lbs. per HP. per hour.

These results, though deserving of record, are not entirely trustworthy, as

^{*}Both as regards the internal waters in the dykes and canals, and the external waters in the boezems, the conditions are usually expressed by the ratio between the water-surface at the normal level and that of the whole polder in the former case, and that of the entire group of polders forming a general association in the latter. Thus the water-surface of the boezem of Delfland is \frac{1}{17}. Each of the separate polders has its own ratio to the internal waters. These two ratios are quite distinct, and express relations which for new undertakings are determined by very different standards. In the case of the polders the ratio depends upon the power of the water-raising machinery, in that of the beezems, upon the regime of the discharge into natural receivers, rivers or sea, subject to tidal action. When wind was the only motive power, this sufficed to drain the polders, but not as a rule the boezems. For them, therefore, the ratio depended generally solely upon the régime of the natural receivers, upon the duration and extent of the ebb tide, and upon the maximum heights which could be given to the banks of the canals belonging to the boezems. For the polders, therefore, the works had to be so arranged that with the ordinary winds, taking into account periods of calm, the land could be kept as far as possible from submersion. The wind-mills had to stop working when the wind failed, and also whenever the water-level in the boezem attained a dangerously high level. With the introduction of steam all these relations were naturally changed. In the case of the boezems the regimen of the receivers still remains a most important consideration, as the greater part of the water must be discharged by natural

that the useful effect is constant.

Backer. and wheel-pumps, and left the choice to of the engineers was to take advantage the constructors, the work being let by tender.

posed by the original inventor. the drum was to be 16.40 feet, two were scribed as under:—

they are founded upon the hypothesis to be 3.61 feet breast, the third 7.87 feet; the external diameter was to be 23.61 Mastenbroek Polder.—This pumping- feet, there were to be twenty buckets of station is interesting from the fact that the form adopted by Rijk at Gouda, with in 1878 three wheel-pumps were erected concavity towards the outer water. The there, which had been very carefully lowest point of the drum was to be at the studied by two engineers of very high highest internal water-level. The axis standing, Professor Henket and Mr. was to be at 5.90 + AP, and the extreme These engineers studied the internal and external water-levels 1.47 subject with reference to both float-wheels AP and 5.92 + AP respectively. The idea of the experience obtained at Gouda, and to produce a perfected float-wheel. These wrought-iron wheel-pumps were The play between the buckets and the of a very different form from that pro- walls was reduced to a minimum by The fastening strips of wood to the edges of specification stated that the diameter of the former. The useful effect was pre-

Lift.	Expansion of Steam.	No. of Revolutions per Minute.	Discharge.	Useful Effect.	Number of Wheels in Action.
Feet. 2.80 6.56	6 7 4 5	5.15 4 19	Cubic feet. 15,892 6,745	H.P. 85 85	3 1 (the large one)

tion of the work there were to be two trials, one carried out by the drivers and stokers of the constructors, the other by those of the association under the direction of the former. The positions of the water-gauges (a frequent cause of dispute) were definitely fixed, that for the internal water at 39.4 feet from the axis of the wheels, the other at 26.25 feet. The second trial was to last for thirty as under, the names being suppressed.

It was specified that upon the comple- | days during the three months in which the constructor was to be responsible for maintenance. In the event of the consumption of coal exceeding that guaranteed by the contract, the contractor was to pay three-fourths of the capital sum which would have to be paid by the association to provide the additional coal.

There were nine tenders for the work,

of Tender.	Price Price for Wheel-Pumps. Price			mption of Coal in	lbs. per H.P. per Hour guaranteed. Float-Wheels.	
No. c	T umps.	Winders.	Lift, 4.26 feet.	Lift, 6.56 feet.	Lift, 4.26 feet.	Lift, 6.56 feet.
1 2 3 4 5 6 7 8	£. 4,831 5,290 5,078 5,375 6,037 6,230 6,361 6,138 8,125	£. 4,792 5,290 5,078 5,875 6,262 6,490 6,563 6,338 8,500	6.06 4.84 4.84 5.50 6.83 7.40 6.61 6.61 5.72	6 06 4.84 4.84 4.95 6.83 6.45 6.61 6.61 5 72	6.50 4.84 4 84 5.50 6.83 7.40 6 61 6 61 5.72	6.50 4.84 4.84 5.50 6.83 6.45 6.61 5.72

The tenders were from first rate constructors, Dutch, German, and English, and are interesting as showing their judgment upon the two systems proposed by the engineers. The prices included the whole of the machinery, with boilers, &c., complete. The contract was let to No. 1, at the rate of £57 per HP. cost of the buildings was £7,166.

The power was transmitted through the axles of the wheels. The ventilation of these wheel-pumps was not satisfactory, though the question had been carefully considered.

The principal dimensions of the engines were: Cylinder 2.3 feet × 4 feet; capacity of the condenser, one-third that of the cylinder; diameter of fly-wheel, 16.40 feet, and its weight 7.38 tons; ratio of transmission, 7.81 to 1. The three boilers were of the Cornish type, 28 ft. 9 in. $\times 4$ ft.

When the author visited the works they had been so short a time in operation that the consumption of coal could not be accurately ascertained, but it appeared that it would be about that of the best engines for water-lifting in Holland, namely, slightly more than 6.6 lbs. per HP. per hour. He considers that the opinion of the engineers is justified, that wheel-pumps and float-wheels are about equally good.

The engine-house is 46.50 feet long, and 18 feet broad. The boiler-house (for three boilers) is 46 feet long, and 27.5 feet broad. The chimney is 78.75 feet high above the fire-grate. Its section increases towards the top, the internal diameter being 3.60 feet at the bottom, and 4.60 feet at the top.

Zuidplas.—This deep lake owed its origin to the extraction of peat. It is not known when this extraction commenced, but there are legal regulations upon the subject as far back as the year 1595. the beginning of the present century, ed to keep down the level of the water in and kept it dry. They were all in action the lake, and in 1825 the Government determined to drain it altogether. The norwas 3.38 feet + AP. therefore, 21.78 feet, and it was decided for the second half.

of which was again subdivided into two parts.

The first principal lift was from the low-lands to a canal, which was carried round the lake at a certain level. From this canal the water was raised to a collecting basin, and thence discharged into the river by sluices. In this way the basin acted also as a regulator to the river, which is subject to great fluctuations of high and low water in times of flood. These regulating works had to be of much larger capacity in those days, when the motive-power was wind, than would now be necessary. The normal water-level in the circumscribing canal was fixed at 13.38 feet above summer level.

The lift was divided into two parts of 6.69 feet each, and the method adopted was that of Archimedean screws, driven by eleven pairs of windmills. From the canal to the river the water was raised in two lifts by means of float-wheels, the lower worked by seven, the upper by five windmills, a part of the discharge into the river being by gravitation at low tide. This arrangement was, however, modified by the introduction of two steam-engines, of 30 HP. (actual) each. These were attached to a couple of screws, which performed the whole lift of (in their case) 22.18 feet at once. The erection of these engines marks an era in the history of drainage. Although the first attempts at using steam-power were made in 1776, near Rotterdam, the only practical application had been made at Arkelschendam, and as these consumed 31 lbs. of coal per HP. per hour, it was thought that steam could not be used economically. The Zuidplas engines consumed 22 lbs. per HP. per hour, which in those days was not considered bad, and led to the adoption of steam for the Haarlem reclamation.

The thirty windmills and the two windmills driving float-wheels were erect-steam-engines emptied the lake in 1840, Each windmill, with its up to 1871. screw, raised the water from 2,352 acres mal level of the water was fixed at 18.40 to a height of 3.28 feet. Each wind-mill, feet—AP. The highest level in the Yssel, with its float-wheel, raised that from 1.into which the water had to be discharged, 898 acres for the first half of the upper The total lift was, lift to a similar height, and from 2,656 The annual cost of to divide this into two distinct lifts, each maintaining these thirty mills was very high, amounting to about £1,800, or

about £60 per mill.

In the meantime the cost and working expenses of steam-engines have been much reduced, while improvements in agriculture require a more perfect regulation of the water-levels, and for these reasons steam has been gradually substituted for wind-power. In 1871 ten mills were removed, and in 1873 it was decided to replace the remaining twenty by steam. A Commission of two well-known engineers was appointed, to whom the following questions were proposed:

- I. What is the best machine for raising 7,240,000 cubic feet of water per twenty-four hours, to a height varying between 11.3 feet and 12.3 feet?
- II. When the height varies between 4.9 and 13.1 feet?
- III. What is the best system of engines and boilers?
- IV. What is the estimated expense?

The answer of the Commission to the second question was decisive: "Centrifugal pumps. No other machine applies so well to differences of level in the external and internal water. No other permits the application upon so large a scale of the whole disposable motive force to all lifts comprised within the limits

"The machine adapted for the maximum lift will, with lower lifts, discharge proportionally larger volumes; while the useful effect which is produced by the coal consumed, does not vary to any great extent."

These statements of the Commission went rather too far. The duty is anything but constant,* and while it is quite true that centrifugals adapt themselves more readily to differences of lift, and are available for much higher lifts than float-wheels, they have this disadvantage, which the Commission failed to point

out, namely, that there exists in each case a minimum velocity, below which they

will not raise a drop of water, whereas wheels, piston-pumps, screws, &c., if working at all, always discharge water.

In reference to the first question, the Commission could not say that one form of pump was superior to all others for a high, but nearly constant lift, and they therefore recommend that as centrifugal pumps should be adopted for the second, they should also be adopted for the first case, as they consider them as good as any other form for the purpose, and by having the whole of the machinery from the same firm there would be a saving in

The selection of centrifugal pumps was subject to certain conditions. They were to be direct-acting, the disks to be above the internal water-level, and the deliverypipe was to be carried by a bend below the low-water level of the external water, so that the lift would vary with that level. Each pumping-station was to have two centrifugal pumps (Gwynne's pattern), driven by separate non-compound directacting engines, capable of raising 2,542 cubic feet of water each per minute. The diameter of the disk was to be not less than 6 feet, and the velocity one hundred revolutions per minute. The suction and delivery-pipes were to be at least 3 feet in diameter. The lower station was to have four, the upper three, Lancashire boilers, 25 feet \times 6.5 feet, with twentyfour Galloway tubes. The maximum consumption of coal was to be 6.61 lbs. per HP. per hour, with lifts varying from

The recommendations of the Commission were adopted, and in 1876 the new machines were set to work.

Tables are given of the performances of the machinery, but before discussing them the author makes some observations upon the float-wheels adopted. For the lift of 11.8 feet, the diameter of wheel is 32.8 feet, which is believed to be the largest in Holland, though similar wheels, of a larger diameter, are used in Italy. Mr. Forster gives a formula for calculating the diameter as follows: Given i, the immersion of the paddles, p the lift, then the diameter D=9.82 $\sqrt{i+p}$ =9.82 \sqrt{H} , in which H = the height from the lowest point of the wheel to the highest external level to which the water has to be raised, the measurements being in feet.

The Dutch use smaller diameters, part-

^{*} Mr. Backer, one of the commissioners, has since expressed another opinion founded upon his later experience ('Rapport over den Waterstaatstoestand'), that the consumption of good coal per HP. per hour for centrifugal pumps when working at their full power varies with the lift, and is, for hits of 7.2 feet, 6.1bs.; for lifts of 1 foot, 2.4 feet; and from 3.3 feet to 5.3 feet, 9.37 lbs., 8.82 lbs., and 7.71 lbs. respectively, not counting the coal required for getting up steam, which he puts at 4 per cent. in his own case, but which ies with the number of interruptions to the work.

ly on account of the great weight of their wheels, partly from being accustomed to wind-power, for which they are more suitable. At Katwijk, where the wheels of most recent construction have a lift varying from 12.14 feet to 13.17 feet, the diameter is only 31.17 feet, while, according to the Italian custom, the diameter of the lowest lift should be 39.6 feet. At Zuidplas, i = 3.28 feet, p = 11.8. D should therefore, by the Italian rule, be 38 feet. It is only 32.8 feet. It should be observed, however, that the Katwijk wheels are similar to those used in Italy, but those at Zuidplas have curved paddles, on Korevaar's system, and for this reason the diameter is less than it otherwise would be, as also is the immersion. this type the inventor gives D=2H as the minimum diameter.

The author has several times seen the Zuidplas wheels at work. When the levels are favorable the wheel enters the water well, meeting it with the edge of the float; but the lower wheel, which has a high lift, does not leave the water as it should, but throws it to an unnecessary height. The upper wheel, however, with a lift of 8.20 feet, acts better. For the lower, the diameter of 32.8 feet is too little for the lift of 11.8 feet, notwithstanding the curvature of the paddles. This curvature, which is concave towards the internal water, has a disadvantage attending it, that when the level of the internal water lowers to such a depth that the convex surface, instead of the edge of the paddle, strikes the water, it drives the water backwards to a certain extent, instead of carrying it forwards.

The author now refers to the actual results of the working of the various machines at Zuidplas. There is this notable feature about the works, that there are two pairs of pumping-stations, with machines of two different types, while those of one pair are identical in construction, and work under different conditions as to lift. The volume of water discharged may be consumption per HP. per hour was taken as constant for each pair. Tables show that neither with paddlewheels nor with centrifugal pumps is the consumption of coal proportional to the lift, or to the work done. In the case of the wheels, the contract specified that the actual H.P. should be 90 each, and the total consumption of coal (Ruhr of the first quality) should not exceed 595 lbs.

per hour with any ordinary lift, with a penalty or premium of £1 13s. for each 2.2 lbs. over or under 595. It is hardly necessary to observe that the trial proved satisfactory and obtained a premium. In practice, however, the upper wheel especially was far from satisfying these conditions. The lower wheel, though apparently working under much less favorable conditions than the upper, gives a considerably better effect, owing to the fact that with these wheels the effect increases rapidly with the lift. The weight of each wheel, with its axle, is not less than 21 tons. The velocity of periphery is about 6.5 feet per second. The actual discharge of these wheels is 92 per cent. of the theoretical. It amounts to 3960 cubic feet per minute for each wheel, and the lift being 11 feet 9 inches, the actual H.P. is 89. The consumption of coal in ordinary work-

ing is 7 lbs. per H.P. per hour.

It should be observed that while the wheels very frequently worked day and night, the centrifugal worked generally at intervals, and sometimes for very short periods, as, whenever the state of the tide permitted, the water was simply discharged by gravity through sluices, but the boilers were nevertheless kept in steam, and the consumption of coal reduced to pounds per HP. per hour, is no doubt greater than it would have been had the pumps been working continuously. The tables given in the Paper show that the duty of the wheels was somewhat better than that of the pumps, but no doubt this is partly accounted for by the above circumstance. In these pumps the power measured by the water raised varies from 40 to 49.7 per cent. of the indicated HP., and the consumption of coal is 7.67 lbs. per actual HP. per hour.

In one respect, however, the wheels are decidedly more economical, namely, the consumption of lubricants. An inspection of the books for 1877 shows that the

			Pint.
For the	wheels		 .0.0053
	centrifugals	 	 .0.0135

The principal dimensions of the buildings are.

For the float-wheels— Outside length of engine and boiler-house...69 width of engine-house37

boiler-house.....40

For the centrifugals—	et.
Internal dimensions of room for two	et.
pumps	$\times 28$
Internal dimensions of boiler-house36: Coal store (not roofed)98:	
Engine driver's house33	

The two steam-engines, with the two wheels of 32.8 feet diameter, and another, not working, of 16.4 feet diameter, cost £5,000, or per HP. £28.

The four centrifugals, with engines and boilers, cost £11,833, or per HP £46.

The cost of the buildings is not given. Mr. Korevaar says that the cost in pounds of float-wheels, including all machinery and buildings complete is 666+66 k, in which k is the horse-power. This rule applies to all powers between 6 and 100.

Bullewijker - polder.—At this polder very careful experiments have been made by the engineer, Mr. Elink Sterk, upon the performances of the centrifugal pumps supplied by Messrs. J. and H. Gwynne, of which the following are the dimensions:—

	Ft.	In.
Diameter of steam-cylinder	1	8
Stroke	1	6
Diameter of the disk of the centrifugal		
pump	5	7
Width of blades at the periphery	0	$5\frac{1}{2}$
Angle of the blades at the periphery	17°	_
" axis	90°	
Diameter of the suction and delivery		
pipes	2	6
Cost of engine, pump and one boiler		
	£.	
(heating-surface 743 square, feet)	2,1	
Cost of reserve boiler	4	72
m . 1		00
Total cost	2,6	26

This is exclusive of erection, and of suction and delivery pipes.

OBSERVATIONS ON THE CONSUMPTION OF COAL.
Lift from14.3 feet to 15.3 ft.
Discharge per second,
maximum 41.8 cu. ft. per secon
Discharge per second,
minimum32.5 cu. ft. per secon
Discharge per second,
mean
Mean effective H.P62.219 "
Consumption of West-
phalian coal during 1,938 lbs., or 5.22 lb
the experiments, per H.P. per hour.
which lasted $6\frac{1}{20}$ hrs.
Number of revolutions,
from
Pressure in boiler, from 66 to 76 lbs.

EXPERIMENTS WITH THE INDICATOR.

Ratio of effective to indicated H.P. from 0.583 to 0.587

In these experiments the water was measured very accurately. The results are the more satisfactory because the suction and delivery pipes were unusually long, 49 and 85 feet respectively. These pipes are not of constant diameter, but diminish as they approach the pumps.

It appears that in Italy centrifugal pumps have been discredited, owing to unsatisfactory results obtained from a set erected at Codigoro in 1874 by Messrs. J. and H. Gwynne, and the author is desirous of pointing out the great improvements effected since that date.

North Sea Canal.—In order to regulate the level of this canal, which receives the waters of very extensive boezems, and of the polders formed upon the bed of the Y, the company have been obliged to erect several pumping-stations, of which the principal is that of Schellingwoude, near Amsterdam. A peculiarity of these pumping-stations is the application of Appold's turbine pumps, which the author describes.

The results were by no means satisfactory, the consumption of coal being not less than 11 lbs., but it is to be noted that the actual quantity of water raised was in excess of that for which the engines were designed, and it was upon this latter that the calculations were made; also that the lift was less than was expected, which would partly account for the excessive consumption. These turbines, in consequence of these results, are now never used.

d. Turbine pumps on a very small scale are used for draining small areas of about 75 acres, with lifts of less than 1 foot 6 inches. They are made of wood, and driven by wind power. They occupy a space of 4 feet by 4 feet, and cost between £16 and £25.

Except in this diminutive scale turbine pumps are not now in request in Holland.

In Italy on the other hand they are said to answer well.

City of Rotterdam.—Rotterdam has three pumping-stations with machinery of an entirely different character to any of those previously described. Their use is to regulate the water-level in the suburban part of the town called Polderstad. They discharge water into the Meuse, and also introduce fresh water from the river into the canals. The canals are greatly polluted by sewage matter.

There are three pumping stations, two of which are provided with lift and force pumps, the third with a Fijnje's pump,* which is driven by an engine with a cylinder 2.75 feet×6.89, the size of the pump being 6 feet×4.92 feet. The cost of the whole machinery was £4,166, or

£104 per HP.

A table is given, showing the performance and duty of this and the other two

pumps at Rotterdam.

Fijnje's pumps are very simple, but have the disadvantage of requiring deep foundations.

HaarlemLake.—A description Dutch pumping machinery would be in complete if no mention were made of the three pumping-stations which have dried up and keep drained the former lake of Haarlem, covering an area of 44,480 acres. The emptying of the lake was begun in 1849 and finished in 1852. A table prepared by the engineers, Mr. Van de Poll and Mr. Elink Sterk, is given, showing the performance of the engines at the three stations, Cruqius, Lijnden, and Leeghwater. The dimensions of these machines are:—At Leeghwater, engine cylinders, small, 7 feet, large, 12 feet diameter, stroke 9.3 feet; pumps, 11 in number, diameter 5.25 feet, stroke 9.3 feet. At Cruqius and Lijnden, the diameters of the cylinders as above, stroke, 8.86 feet; pumps, 11 in number, diameter, 6 feet, stroke, 8.86 feet Ratio of the effective to the calculated discharge (at the normal velocity), for Leeghwater about 84 per cent. (this is somewhat doubtful), for Cruqius 89 per cent. (this figure is reliable). The consumption of coal as found by records extending over

a considerable time is 6.83 lbs. per HP. per hour.

Mr. Sterk made some experiments with a view to ascertain the difference in working at the normal speed of about 7 strokes per minute, and when this was reduced to 3 strokes. With seven pumps at work, he found that in the latter case the indicated HP. was 192, the effective 134 HP., or 0.698 of that indicated. The consumption of coal was 5.44 lbs. per indicated, and 7.80 lbs. per effective HP. per hour. When working 7 strokes per minute, the indicated HP. was 492, the effective 361, the consumption of coal 4.94 lbs. per indicated, and 6.74 lbs. per effective, HP. per hour.

The coefficient of useful effect of the pumps is higher than that of any other machines in Holland; that of the motors on the other hand is small, and the consumption of coal per indicated HP. per hour is more than double that of good

modern engines.

Comparative Notes upon the Various Systems.—Besides those described, various other hydraulic machines are in use in Holland, notably a species of Archimedean screw, which is very simple in construction and easily erected. It is well adapted for working by wind-power, and is a most useful machine for lifts which are too high for wheels. It requires, however, that the level of the external water should be nearly constant.

From analytical investigation, and from experiments carried out under certain conditions, it would appear that the best hydraulic machines are piston-pumps, and the worst centrifugals. Notwithstanding this fact, however, it is certain that in Holland, where pumping-machinery is used to such a very large extent, centrifugal pumps are preferred, and piston-pumps are the least used. In all pumping-machinery the duty varies greatly with the lift; this is recognized by the makers of centrifugals, so that in recent contracts at least three conditions of lift are specified, and for each the consumption of coal per HP. per hour is fixed. In the opinion of one of the principal Dutch authorities, the mechanical effect differs much less than is imagined between different classes of machines, and in designing a new establishment the greatest importance should be attached to other circumstances; such as the turbidity of

^{*} These pumps were first used in Holland in 1847. They have since been introduced into Germany, and lately into America, where, owing to their success at the Philadelphia Exhibition, they have been applied on a large scale at several places.

the water, the probability of the internal water-level being permanently lowered in time, the nature of the foundations, the method of establishing communication between the inner and outer water, the level at which the machine can be placed with reference to the water to be discharged, upon which depends to a greater or less extent the facility of superintending and repairing the machinery, the security against inundations, the frequency of frost, &c.; also the cost of erection and working.

When flood-water conveying a large amount of débris has to be raised, pistonpumps are unsuitable, as they are liable to be damaged, and to have their valves choked. Centrifugals are better in such cases, but wheels are the best, and they have the further advantage that they can be easily repaired by ordinary workmen. The motors may be of common types, the only difficulty being that of adapting them to low velocities. With a diameter of 30 feet for instance the wheel must not make more than four and a half revolutions per minute, and with a single system of gearing the speed of the engines would have to be limited, for, with an ordinary speed of 70 strokes per minute, the ratio of transmission would be

15.5, which is too high. On the other

hand the tendency is to construct engines to work at high speeds, as being more economical.

Again, the system of direct action between engine and pump is the one which is most economical in fuel, but here the difficulty is that too high a velocity is required; for instance, at Legmeer, the engine makes 168 strokes per minute.

In regard to foundations, wheels are at a disadvantage compared to centrifugals, for, with a high lift the wheel must have a large diameter, the sill must have a low level, and this necessitates massive and deep masonry. In some cases this question of foundations is a very important one, and would determine the kind of machinery employed.

Another important point is the liability of the internal water to have its level permanently lowered. With machines in always be added to the piping, and the come to as to what machine to use.

only difference is that the consumption of steam will be greater, but with wheels, screws, and possibly with force-pumps, a lowering of the level of the water would require costly alterations.

It is well known that such alterations of level occur in draining marsh-lands, and their amount varies with the nature of the soil; their extent is small in the case of sand, larger in clay, and greatest

in muddy ground.

In regard to the separation between internal and external waters, the easiest and safest arrangement is that of pumps which discharge the water through pipes which are inserted in masonry walls of sufficient thickness. With wheels and screws much larger apertures are required, and these must be protected by strong sluices.

The Dutch hydraulic authorities state as general principles that for lifts above 16 feet 6 inches, wheels cannot be used, as their diameter would be too great. When the level of the external water is subject to great fluctuations screws cannot be used, as the amount of fluctuation allowable depends upon the radius of the screw, which cannot be more than 4 feet. When the water is very turbid, valve pumps are inadmissible; for moderate lifts, particularly when pretty constant, they recommend float-wheels, if for no other reason, on account of their simplicity and well-known durability.

It may be stated in general, that the useful effect of every machine varies greatly with the lift, and that in estimating the consumption of fuel, it is not enough to take the mean ordinary lift, but the variations must be studied and grouped together, the consumption due to each lift per HP. per hour must be computed from the results of existing machines.

The following table shows the number of pumping machines of different types erected in Holland in the years 1875 to 1881:--

(See table on page 295.)

The author concludes from the result of his investigations that no general rule can be given as the employment of one or other of the different machines, but which the water is conducted to the that all the circumstances of each case pump by pipes, additional lengths can must be considered before a decision is

	1875.	1876.	1877.	1878.	1879.	1880.	1881.	Totals
Float-wheels	3	1 1	1 6	4 6	12 11	9	8 16	38 50
eombined. Wheel-pumps. Serews Piston-pumps.	_ 3 _	_ _ 1	$\frac{-}{7}$	$\begin{array}{c} 1 \\ 1 \\ 2 \\ 1 \end{array}$	<u>-</u> 12	1 1 4	$\frac{1}{2}$	3 2 30 4
Various	$\frac{3}{10}$	<u>-</u>	17	21	35	25	28	12 139

APPENDIX.

While the proofs of the last sheets were being revised by the author, he received a copy of the "Tijdschrift" of the Dutch Institution of Engineers, containing a paper by Mr. Korevaar, entitled, "What are the most suitable machines for keeping polders drained?"

Though Mr. Korevaar does not in all cases agree with the author's conclusions, the latter sees no sufficient reason for changing his opinions.

Mr. Korevaar begins by saying that the only machines which deserve discussion are float-wheels, wheel-pumps, suction-pumps, lift and force-pumps, and centrifugals. He considers that all are effective when rightly proportioned, and that the first outlay does not differ much between them. The real point to be considered is the expense of working, and he endeavors to ascertain what are the most economical in this respect. But first he gives certain rules as to the discharge and lift suitable to each class of machines.

Float-wheels are capable of discharging 8800 cubic feet per minute, and have the advantage that they can be worked at any lift up to the maximum for which they are designed without any useless raising of the water. They will work up to a lift of 12.3 feet, the ordinary limit being 9.84 feet. For screws he states that if the external water-level descends more than about 1 foot 6 inches below the maximum there will be a wasteful lifting effect. Limits of lift and discharge are 14 feet and 3,500 cubic feet per minute. For suction pumps he gives 2,120 cubic feet and 16 feet 6 inches; for double-acting lift and force pumps in pairs a discharge of 5,300 cubic feet per pair, and of each particular case previous to decid-40 feet or more lift. He estimates the ing what machine to adopt.

maximum discharge of centrifugals at 3,500 cubic feet, and lift 40 feet.

Mr. Korevaar gives the following as the ratios between useful effect and indicated power in the cylinders:—

Float	-wheels	 .0.67
Lift a	and force-pumps	 .0.70
Centr	rifugal pumps	 .0.45

He also describes investigations carried on at fourteen pumping stations from September 1880 to May 1882 into the consumption of coal by the different classes of machines, the results of which he gives thus in hectoliters of coal consumed per hectare and per meter of lift:---

	Hectoliter.
Float-wheels	1.06
Lift and force pumps	1.06
Similar pumps combined with fl	loat-
wheels	1.04
Centrifugal pumps	1.77

Whence he concludes that centrifugals consume at least 50 per cent. more coal than the other machines.

The author does not agree with Mr. Korevaar, whose condemnation of centrifugals he considers to be based upon somewhat unfair treatment, those experimented upon being of old-fashioned types, and working under unfavorable conditions. He also, however, considers that centrifugals consume more coal than any other class of pumping machine, and that suction-pumps consume less. insists again, however, on the necessity of a careful examination of all the features

THE CONSTRUCTION OF CHIMNEYS.*

BY JOHN P. SEDDON.

From "The Architect."

integral and important features of ordinary buildings in England. It may be ings—chimneys and fireplaces. that they can and will ultimately be altogether dispensed with, and our towns made, by the progress of economic science, to resemble those in the East-mere collections of flat-roofed boxes; and these may possibly be fed with fresh air of varied temperature, and drained of their fouled air by some parish pump and common heating apparatus. When this scientific millennium arrives, such dwellings may be left to purely scientific men, to whom æsthetic considerations are ques-

tions of superfluity.

I have, however, now to speak as an architect, addressing a sanitary conference, upon chimneys as existent, and I wish to show how they can and should be treated, that they may be practically useful and ornamental as well. Thev have been both in former times; witness the graceful chimney-shafts of Grosmont Castle, Southwell Priory, Hampton Court, and a host of Elizabethan mansions, the acknowledged picturesqueness of which is mainly due to the treatment of their chimney-stacks. Alas! however, they are seldom either useful or ornamental nowa-days, as a glance at the skylines of our streets will reveal, since they are almost invariably disfigured by ugly cowls and "tallboys." These are but records of domestic misery and discomfort, every one representing a martyrdom, endured until it became intolerable; and their aggregate cost amounts to a tax upon the inhabitants of our cities which, were it an enforced one, might lead to a revolution. Yet the makers of such monstrosities occupy no inconsiderable space in this very Health Exhibition, and recommend their wares as palliatives for a disease which they assume to be not only universal but inevitable. I maintain that it is not the latter, and need not be the former, and that such costly and ugly excrescences may be altogether dispensed with, if but a

Now, let me ask, why do our chimneys smoke? Firstly, because, as a rule, air is not laid on or provided to houses as water is; but rather, indeed, it is in general sedulously excluded. The more sanitarily impervious (that is to say, air-tight) we make our dwellings, the more necessary it is to provide for the admission of fresh air to their interiors, and, unless this be done, smoke cannot ascend the flues of their chimneys; secondly, chimneys smoke because the fireplaces are ill-constructed, and gathered over from the openings of the fireplaces to the flues in such a gradual manner as to leave large vacant spaces above the grates, which act as reservoirs for stagnant cold air, by contact with which the smoke is chilled and prevented from rising and being drawn at once into the flues; thirdly chimneys smoke because flues are ordinarily made too large (the usual size is 14 inches by 9 inches); they should rarely be made more than 9 inches by 9 inches; fourthly, because no provision is made in the flues for such down draughts of air as may invade them to expend and exhaust themselves before they reach the fire-place; and fifthly, because the tops of the chimney-shafts are not carefully constructed with guards against wind in a proper and sightly—that is to say, an architectural manner. Usually all such provision is left to be supplemented by some miserable metal makeshifts, by the chimney-quacks whose fantastic creations Dickens satirized so keenly, and yet, as it would appear even from this exhibition, quite vainly.

As it is useless to expect that chimneys can properly perform their office, of conducting readily into the outer atmosphere the smoke from fireplaces, unless their construction is proper throughout, I shall treat of the fireplace, flue and chimney-top as a whole, of which the several parts are inseparably connected; and I shall begin at the bottom with the fireplace, as the most important of the

Chimneys, at present at any rate, are little attention be given to the proper construction of these portions of our build-

^{*} A paper read at the Conference of Architects at the International Health Exhibition.

fault in the case of smoking chimneys, although it is generally the last to be noticed or examined with a view to its The grate itself, however, I correction. shall leave for later consideration, though it is by no means of the least import-

vide a good and sufficient supply of fresh . air to the fireplace from the outside of the building. To insure its being good from as high a level as can be arranged, yet not from the top of the chimneydrawn down thence with the fresh air. It may be drawn from the lower part of the stack, just above the roof, by special air flues brought down the chimney This, however, is not always possible, and then it must be brought in through the walls or by pipes through the floors. An advantage of bringing the fresh air to the fireplace, rather than to any other part of an apartment, is that even if cold, it does not produce the inconvenient draughts usually complained It spreads thence upwards and gradually, before being finally drawn up the chimney by the fire in the fireplace; whereas, if admitted elsewhere, its passage is direct to the fire, and unpleasantly so to those who may intercept its course. When no provision for air is made, it has to force its way in at windows and doors, with the same result, made all the worse because of the low temperature at which it enters. The air, however, brought to this point, may be tempered or warmed by being made to pass around apartment, and an essential for both comtempered; every grate, stove, or heating apparatus should, in fact, be thus made the fountain or source whence fresh air is admitted to apartments.

The next point to be considered is that of the outlet of the smoke from the fireplace to the flue. The flue should be flat ledge should be provided in this exhere contracted at once to its normal panded part of the flue, immediately size, or rather made a little smaller, im under the smoke-flue above, that air mediately above the fireplace, in order to driven down may imping upon it, and promote a quick draft of the smoke into be diverted, and a sideways rotary moof chimneys, already adverted to, does again, together with the smoke rising not conduce to this end. The opening from below. Specially formed pipes can

three, and the one most commonly in of the fireplace is gathered gradually, in an arched form, to the flue, leaving an objectionable space for cold air. arch and chimney-bar may be economically dispensed with by forming a mantle block in Portland cement concrete in situ, extending the full width of the wall, and 9 inches longer than the open-The first thing to be done is to pro- ing, and 9 or 12 inches deep, pierced with the smoke flue in the center, and one for warmed air on either side. These may be circular, and about 8 inches in it is well, when possible, to bring this diameter, and thus being slightly smaller than the flue over, will insure a quick draft to the smoke flue. The side holes stack, lest smoke from other flues be are intended as outlets for the fresh air that has passed round the grates, and thus can be conducted by flues built above the mantle block to gratings for admitting it into the apartment, either in connection with the chimneypiece, or just

> below the ceiling. The construction of the smoke flue from above the central hole in the mantle block is the next point deserving and requiring consideration, As has been said, this is ordinarily made 14 inches by 9 inches, but this is too large, and as such becomes a frequent cause for smoking chimneys. Flues should not generally be made more than 9 inches by 9 inches in brickwork, and are better if lined with fireclay pipes within such, which reduces them to about 8 inches in clear circular diameter. The interior surfaces of the pipes should not be smooth, or else much inconvenience will be caused by frequent small falls of soot, from its being unable to cling to the pipes at

Midway between the top of the mantle the grate before it is admitted to the block and the ceiling line of the apartment, the smoke-flue should have a porfort and health is that it should be so tion expanded and formed in such a manner as to break the direct line of ascent of the smoke. This is in order to allow down draughts or gusts of air that have invaded the flues from the top to expend themselves, without checking the smoke as it rises from the fireplace. A The usual construction of this part tion given to it, directing it upwards

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than one of these may be inserted in of this Conference. the course of the flues with advantage.

object in its construction is to maintain rest with which I have dealt, but what I throughout its warmth, as it is there of have to say about it is somewhat more course exposed to cold and damp; and it tentative and experimental. This is the is well known and observed that those grate within the fireplace. chimneys which are in external walls are, have been written about it, and yet it becomes saturated by rain, and the flues consequently reduced in temperature are unable to maintain the requisite upward draught. It is well, therefore, for this that the chimney-stacks above the roof common mortar, and of impervious bricks or stone and lined with fireclay pipes.

The tops of the chimney-stacks need careful arrangement, because the exit of the smoke from them is very liable to be disturbed and hindered by gusts of wind, particularly when beneath other high objects in the neighborhood. There should, therefore, be at the top of every flue an expanded space, within which most down low; and there should be louvred open- escape up the chimney flue. stead of metal. cated forms required for the purpose.

these three parts of a chimney, the fireplace,

be introduced into flues lined with fire- fected by their general neglect, I earnestclay pipes for this purpose, and more ly commend them to the consideration

There is, however, one more part con-We now have arrived at the chimney-nected with the chimney, which is perstack above the roofs, and the principal haps quite as important as any of the Volumes from this cause, far more liable than remains open for discussion and inviting others to smoke. Pervious brickwork improvement. My contribution to its literature will be short, and yet it-will embody the result of much time and

thought expended upon it.

Burning coal principally, as we do in reason as well as for additional strength, England, we have to seek in the consumption of its smoke, or at least of as should be built in cement instead of large a proportion of it as possible, within the grate itself, the solution of the main difficulties we are considering. For the smoke being consumed, smoky chimneys will be cured. The office of the flue will then be to convey away the gaseous products of combustion only, and not soot. This is, I believe, attainable by means of diverting the current of the smoke, after it has issued from the top of the fire, in such a manner as draughts of air will rotate and expend to force it to pass through the body of their force without invading the flue be- the fire before it ultimately is allowed to ings so arranged as to direct the wind combustion is, I think, more to be sought upwards, and so make it to assist, instead than what is called "slow combustion," of interfering with or retarding, the exit and it is a mistake in my opinion to of smoke. This is the object generally smother a fire in its own ashes, by preand often rightly attempted by the supplementary cowls, at any rate by the best into an ashpan. The cheerful aspect of of them, but it may and should be rather an English open fire is not likely to be executed in proper architectural form, driven out of fashion by even Health Exand durable and sightly materials, such hibitions; nor if it could be, and the atas stone, brickwork or terra-cotta, in- tempt were made, do I think that the Terra-cotta is perhaps public salubrity would be improved by specially suitable, as being very easily the substitution of any description of manipulated into the somewhat complicions stoves in apartments, notwithstanding the preference they have obtained on So much, then, for the construction of the Continent, and to a great extent in Nor do I believe that any America. the flue, and the chimney terminal of the of the systems that have been proposed stack. Unless all are well and properly for keeping up throughout dwellings an executed, no special appliances for par- equable temperature, are likely long to ticular parts can be of much avail. I curtail the liberty of English subjects to have endeavored to point out the general make their several rooms of whatever principles that I think should be attended degree of heat it may please their octo in connection with them, and believing cupants. I should certainly, therefore, that the health and comfort of the com- not advise the most ardent believer in munity is at present very injuriously af- such a system to expend capital in building houses otherwise than at present, ing wanted in the kitchen, should be or to try to dispense with chimneys, the construction of which I have been dealing

But there are many grates shown in this exhibition which presume fresh air to be brought to them, and in which means are provided for warming and distributing such air into apartments, and I cannot too highly commend the system, and advise its universal adoption by the public; and I may point out that this can and should be done, more often than it is, in the case of the kitchen chimney, which is almost always in use, and that the air warmed thereby not be-members of this Conference.

conducted to the general hall of the house, which supplies air to the rooms whenever their doors are opened, though of course there should be means of shutting it off in summer, when it might prove rather a nuisance than otherwise.

Trusting then that soon, if it be not already achieved by any of the grates shown in this exhibition, that most desirable end, the consumption of smoke within the grate itself will be successfully carried out, I conclude these few observations upon the construction of chimneys, waiting discussion thereon from the

VENTILATION IN CONNECTION WITH WARMTH AND LIGHTING.*

BY CAPTAIN DOUGLAS GALTON, C.B., LL.D., F.R.S.A.

From "The Building News."

In this lecture I propose to endeavor less hurtful to our atmosphere. to explain what are the principles which open fire is the most favorite method of practice. We must all agree that our present arrangements are inconvenient in certain respects, so far as our towns are concerned. When we bring a large number of houses together, as we do in our great cities, the methods which we adopt for warming our houses conduce to the smoke and pollution of the atmosphere. The amount of coal which we burn is out of all proportion to the heat which we produce. Therefore, in our towns, the methods to which we resort for warming our rooms load with impurities the air which we have to breathe. Those who have been born and have lived in the heart of London, do not know what the feeling is of breathing fresh invigorating country air. The question is: How can we alter this? alteration is to know what conditions we want to obtain. We will consider, in the first place, what advantages our present methods of warming secure for us; and next, how we can secure these in ways

should guide us in warming our houses, warming. So far as the production of and then to endeavor to show how those heat is concerned, it is also the most principles can be usefully employed in wasteful. One pound of coal is more than sufficient, if all the heat of combustion is utilized, to raise the temperature of a room 20 ft. square and 12 ft. high, to 10° above the temperature of the outer If the room were not ventilated at all, and the walls were composed of nonconducting materials, the consumption of production of a very large amount of fuel to maintain this temperature would be very small; but we must change the air of the room if we are to live in it, or else the act of breathing would render the air so impure that we should die. The air which passes out of the room to make way for fresh air is warm, and carries some heat with it; the fresh air which comes in, if cold, absorbs heat, which brings up its temperature to that of the room. All this entails a development of additional heat. For instance, The first step toward if the volume of air contained in the room above mentioned were changed every hour, one pound of coal additional would be required per hour to heat the inflowing air, so that to maintain the temperature at 10° above that of the outer air during 12 hours would require 12 lbs. of coal. Besides this, there is a continual

^{*} A paper read at the Health Exhibition, July 18,

mere circumstances of occupation of a heat. Thus brick or tiles are better than room entail a greater consumption of fuel than the mere 1 lb. of coal in order to maintain the temperature. But the open fire consumes much more than would be necessary to keep up the heat. The principle of the ordinary open fire-place is that the coal shall be placed in a grate, to which air is admitted from the bottom and sides to aid in the combustion of the coal; and an ordinary fire-place, for a room of 20 ft. square and 12 ft. high, will contain from about 15 lbs. to 20 lbs. at a time, and, if the fire be kept up for 12 hours, probably the consumption will be about 100 lbs., or the consumption may be assumed at about 8 lbs. of coal an But the consumption of fuel enables the open fire to perform other functions besides those of warming. It is a great engine of ventilation. One pound of coal may be assumed to require, for its perfect combustion, 160 cubic feet of atmospheric air; 8 lbs. would require 1,280 cubic feet; but at a very low computation of the velocity of the gases in an ordinary chimney-flue the air would pass up the chimney at a rate of from 4 ft. to 6 ft. per second, or from 14,000 to 20,000 cubic feet per hour; with the chimneys in ordinary use, a velocity of from 10 ft. to 15 feet per second often prevails, giving an outflow of air of from 35,000 to 40,000 cubic feet per hour. We have, therefore, to consider the open fire in two aspects: —1. As a method of warming. 2. As an engine of ventilation. In its aspect of warming, the radiant heat from the fire does not warm the air of the room; the rays from the fire warm the sides and back and parts adjacent to the grate, they warm the walls, floor, ceiling, and the furniture of the room, and these impart heat to the The form and material of the fireplace can thus assist materially the warming of the air. The rays should impinge more freely on the walls and floor than on the ceiling. A projecting chimneypiece with a surface favorable to the absorption and emission of heat would be more favorable to the warming and circulation of the air than one which would allow the rays to pass to the ceiling. In ant heat, and as it warms the walls of the an ordinary fire-place the sides should be room and the furniture, it takes off any splayed, as in the Rumford form of grate; sensation of chill from the walls, &c.,

escape of heat going on through the ducting material, with a surface favorable walls, windows, ceiling, etc., and thus the to the rapid absorption and emission of iron for this purpose. Similarly, the degree to which the materials of the walls or floor of the room are unfavorable to conduction, but favorable to the absorption and emission of heat, will have a bearing on the capacity of the room for warmth. The open fire, moreover, has this advantage: that a person can obtain just as much or as little heat as he desires by placing himself in front of the fire or at the side. There is, however, this inconvenience about the open fire. large volume of air drawn out of a room by the chimney must be supplied from somewhere, and consequently the very means adopted to heat the room tends to produce draughts, because the stronger the direct radiation, or rather the brighter the flame, in open fire-places, the stronger must be the draught of the fire and the abstraction of heat. Let us next consider what are the conditions which we require for comfort. The normal temperature of the human body is 98° Fahr. If it rises much above or falls much below that, death will ensue. But the human body is a furnace in which the process of combustion is continually going on. Therefore, in order to preserve the normal temperature, the body must continually give off a certain amount of heat. By the laws of radiation, a heated body parts with its heat more or less rapidly in proportion to the low or high temperature of bodies near it. Thus, if a hot body be placed near a cold body, the hot body will radiate heat rapidly. If the hot body be near a body less hot than itself, but still hot, it will part with its temperature slowly. Let us apply this to a room. If you are sitting in a room near a cold brick wall, you feel what you think is a draught. It is not necessarily a draught at all. But the side of your warm body turned next the wall parts with its heat rapidly, and you experience a local chill. If you hang a piece of carpet against the wall, the draught is no longer felt, because the carpet checks the rapidity of the radiation. Now, the chief source of heat in the open fire is its radithe sides and back should be of non-con-although the air may be comparatively

cool. You must next bear in mind that the the public mind to this want. So far as proportion of radiant heat to the total heat given out by a heated body, depends use from our midst, there is hope that on the temperature of the body. Thus, with a red-hot piece of iron, or a flame, the great part of the heat given out is radiant heat; whereas, with a body heated to from 150° to 200°, like a hot-water pipe, a comparatively small proportion is radiant heat. Therefore, when you heat a room by means of hot-water pipes, or by means of warmed air, the walls do not get warmed in the same proportion, and although the air may feel warm, the walls another matter, and I fear that it will be may remain cold, so that the heat of the body may be radiated to the walls and give the sensation of chill. I confess that personally I think there is nothing to compare with what my friend, Sir F. Bramwell, calls the pleasant, pokeable fire. But I do feel most strongly that, however much private feelings may incline us all to use the open fire, it is our duty, now that our towns are becoming so vast, to adopt some method of heating which will produce less smoke. It is not as if there was any probable and early room is somewhat cooler than the walls. limit to the size of London or of other Now there is undoubtedly greater exhilaand London has progressed at the same than by breathing warm air. upon as vast and abnormal. It now conour air, it ruins our furniture, our picture, for comfort in breathing. crease of London, this must go on in an accelerating ratio. But it requires edu-

purity of air depends on removal of refin that respect this object may be attained, although no doubt even this simple question is much neglected. Dust is generally removed in open baskets, and emptied into open carts, in a manner which seems to have been designed for the purpose of scattering it as much as possible into the surrounding atmosphere. But the purity of air which depends upon the absence of smoke is many years before the selfishness of the community will give way on this point. The first point to consider is, if we dispense with the use of the open fire, how can we obtain that comfort which the open fire-place gives. The comfort of the open fire is due to the warmth it imparts to the floor, the walls, and the furniture. The air of the room is warmed, not by the rays from the fire, but by the warmth imparted by those rays to those various objects. Therefore the air of the large towns. They grow continuously, ration produced by breathing cool air steady rate since the beginning of this readily accounted for. One cubic foot of century. In 1851 it contained a little over cold air contains more oxygen, because it 2,000,000 inhabitants, and was looked is condensed, than the same volume of expanded warmer air. It is thus desiratains 4,000,000, and is steadily increasing. ble that air admitted to a room should The smoke destroys our light, it injures not exceed from 55° to 60° temperatures, our decorations, and with the in- will at once explain to you why the employment of warmed air alone to warm your houses does not give comfort. If cation in the people to get rid of it. The the warmed air is admitted at a comfort-Smoke Abatement Society sounded the able temperature for breathing -viz., first note against this gigantic evil. In about 55°, the walls, which derive their response to the demand then made, many heat from the air, will be somewhat below new forms of fire-place were proposed; that temperature. The discomfort is but the practical conclusion to be derived caused by the warm body radiating its from that exhibition, was that so long as heat too rapidly to the colder walls. we burn our fuel in the raw state in our Therefore, if you are to abandon the open rooms and in our kitchens, we cannot get fire, but retain its comfort. you must rid of smoke. The main object of the warm the walls and floors, &c., of your present exhibition is to educate the peo- rooms. If you can maintain your walls, ple in the science of health. The public floors, and ceilings, at a temperature of has long felt the want of pure water, and from 55° to 65°, combined with an adehas obtained a supply of comparatively quate change of air, you will not experipure water in the metropolis. The publence much inconvenience from the loss of lic has not yet become fully alive to the the open fire, however much you may necessity of pure air. It is our business regret its companionship and its pokeat this exhibition to endeavor to awaken ableness, There are four ways in which

we may effect this. In three of these ways one fire in each house in a central position would be used. In the fourth the heat would be applied in the room itself by means of gas. It is probable, however, that a combined arrangement would be desirable. In all the cases where the heat is furnished from one fire, this fire would be in a close furnace for warming each house, or self-contained block of buildings; and thus the fire could be so arranged by means of selffeeding apparatus as to be practically smokeless. The heat from the fire would be conveyed to the various parts of the building by hot air, hot water, or steam. Where warmed air is used, it would be necessary to adapt the house in its original construction to the purpose, because the air would have to flow up, through spaces in the walls, from the basement. Moreover, it would not be economical to bring up the air in the outside walls, because then nearly half the heat would pass direct to the outer air. The warmed air passing up the central walls of the house would part with some of its heat to the walls, and would thus enter the room at a lower temperature than that of the walls. In order to draw up the warm air into the rooms, it would be necessary to have some means of extracting the air from the room, so as to draw in the warmed air. It would not always flow in of itself in this country. Thus you see that the warming by means of fresh air involves ventilation, and moreover requires, if it is to be thoroughly efficient, that your architect should have thought out the whole problem when he first plans the house, and before you build it; otherwise you are met with difficulties at every turn. In the method of heating by hot air alone you have this further consideration: The air in the heating chamber is necessarily at a given temperature, and your house is thus heated uniformly; but it may happen, in this climate especially, that you may want one room to be warm whilst another is cool. It is generally on this account that other methods of heating have been preferred. It is to these methods of heating that I

other places which it is desired to heat. I will at once say that the arrangements hitherto made for warming by either hotwater pipes or steam pipes have not fulfilled the conditions I have mentioned as being necessary to supply the comfort of the open fire. The method adopted is to accumulate a certain amount of heatingsurface in a coil or nest of pipes, or in what is termed, in the United States, a radiator; but the plan of distributing the heat by means of a large flat surface placed close to the wall has been generally adopted. I do not wish to imply that it has not been thought of, because some few years ago, in an Exhibition of Sanitary Appliances, held at the Society of Arts, Mr. Pritchett, of Bishops Stortford, suggested something of the sort. The apparatus consists of a series of receptacles, or cases, for water. The cases themselves were formed of ordinary plates of corrugated metal, strongly put together, but having a small interval between them so as to unroll the water, as it were, into a film, and form a succession of reservoirs of water, about 30 in. in height, more or less, as is required, but only from \frac{1}{3} in. to 1 in. in thickness, enabling them, therefore, to be placed continuously as a dado, or as a series of panels, round any room or building intended to be warmed, and occupying scarcely any appreciable portion of the space of the room or building. The corrugated form given to these reservoirs not only increases the area of the external surfaces, back and front, and imparts strength to the vessels, but secures a certain amount of friction in the action of the warmed water within the vessels, which predisposes it to part with its heat during its circulation. I have never seen this applied in practice on a large scale. These panels might conveniently form the dado of a room, and, if six feet high, would insure the comfort of the occupants of the room, as they would effectually prevent persons in the room from radiating the heat from their persons to the surrounding walls. Such panels all around the room would especially lend themselves to warming fresh air to be admitwould now direct your attention. These ted into the room. Mr. Pritchett promethods are hot water pipes, or steam posed that these should be warmed by pipes, led from the fire, which is placed the circulation of hot water; but it is in some central position and arranged to certain that it would be more advantaaccumulate the heat in those rooms or geous to employ steam to heat them if they

were established on a large scale. In ing that the condensed water should flow England, steam is not much employed back to the boiler. for heating. We are prejudiced against called closed circulation, with separate it. We fear accidents. It is, however, supply and return mains, both of which a method of conveying heat which is emi- extend to the furthest distance to which nently suited to use on a large scale; and the heat has to be distributed. It is, howif we are to hope to abolish our smoke ever, possible to carry the steam and nuisance, it is by methods of heating on bring back the condensed water by means a large scale only that we may succeed. of a single main, which answers at once Steam heating is extremely simple in its for both the supply and the return, either application. Steam is easily led to great with or without a longitudinal partition distances. Steam heated pipes are hotter inside it for separating the outward curthan hot-water pipes, therefore their effect in warming the air in contact with rent of condensed water. If more conthem is also greater; and, therefore, venient, the return of the condensed when heating is required on a large scale, water to the boilers may be dispensed it will be found that it is more economi- with, and the steam may be applied in cal to use steam pipes than hot-water what is called the system of open circulapipes; besides which, the pipes may be tion, where a supply main conveys the smaller, and thus in both ways expense steam to the radiating surfaces, whence a moreover, radiate a large portion of their water either into an open tank for feedheat to the walls and furniture of a room. ing the boiler, or into a drain to run to Heating by steam is universal in the waste, or for use as hot water, the boiler United States, and the usual system may be described as follows: The steam is in either case suitable traps have to be conveyed from the basement along pipes provided on the return main for preservto the room or passage where it is ing the steam pressure within the supply wanted to be used, and there it is passed main and radiators. The difficulty of into a cluster or coil of pipes, called a steam heating lies in regulating the teming apparatus is solely the difference of pressure which results from the more or less rapid condensation of the steam in contact with the radiating surfaces; a partial vacuum of greater or less amount is thereby formed within the radiating portions of the apparatus, and the column diminution of pressure constitutes the ef-

This is what is Highly-heated steam pipes, return main conducts the condensed being then fed from some other source; The difficulty of radiator, which gives an enlarged heating perature of the pipes. With hot water surface. The cause producing the circu- you can have your pipes heated to anylation throughout the pipes of the warm- thing you like from 50° to 180°, but with steam pipes it is different. The heat is got up very rapidly when the steam is turned on, and goes off very rapidly when turned off. There are various arrangements for regulating steam heating when applied to warm inflowing air. In the New York Hospital the incoming air is of steam, or of water, equivalent to this warmed by coils of steam pipes, and generally to a considerable temperature; fective head producing the flow of steam but in order to prevent the warmed air from the boiler, while the return current entering the wards at too high a temperaof condensed water is determined by the ture, this hot air is passed into a mixing downward inclination of the pipes for the chamber, to which cold air can be adreturn course. Therefore, the flow pipe mitted at will, so that the hot air can be should be carried in as direct a line as mixed with cold air to the extent necespossible from the boiler to the highest sary to moderate its temperature before point; all the coils for heating should be it is allowed to flow into the wards. placed on the return pipe, which should There is, however, one great advantage be laid in a uniformly descending line possessed by coils of steam-heated pipes back to the boiler, so arranged as to pre- —they give out a larger proportion of ravent the lodgment of any condensed diant heat to the walls than is given by water on its way there, because, if condensed water lodges in the pipes, most stand how much simpler it would be to unpleasant and startling noises result warm Mr. Pritchett's dados and wall It is a source of economy in steam heat-panelling by steam pipes carried through

them instead of by hot water. The next use it when and where you desire it. way in which heat can be applied is by means of gas. A gas jet warms any surface in contact with it. If, therefore, you turn, and in this climate, where our enclose a gas jet in a metal case, and if changes of temperature in winter are so you bring air to feed the gas burner from rapid, a uniform heat applied everywhere the outer air, and carry away the products of combustion also to the outer air, you can use the heat of the metal case to warm the surrounding air in the room, whilst the fumes of combustion from the gas will be taken outside and do no with soot. Each of the fires in a house harm to the air of the room. Gas jets requires a separate chimney; and as, if might thus be applied with the greatest the householder were determined to do ease to warm Mr. Pritchett's dados and all in his power to make the atmosphere wall panels, the gas jets being placed in-impure, smoke which is arrested in the side the dado, and the products of com-chimney flue in the form of soot is periodibustion carried to the outer air. Boyle has invented a very efficient meth-chimney into the air, not only to the detod of applying gas to warm inflowing riment of the occupier of the house, but air at an ordinary ventilator. It is in to that of the neighbors—an arrangement use at the Guildhall. The fresh air inlet which may be witnessed any morning in has placed in it a pipe which is coiled houses where chimneys are being swept. bottom of the pipe, separate from the air separate fires in every house, and for of the room; the products of combustion pass up the coiled pipe, and then down for a moment, the amount of labor and and out to the open air, the pipe being expense entailed by the mere supply of warmed by the heat they give out in their fuel upon this separate system. Take, as passage, and the fresh inflowing air being an example, one house of moderate size. warmed by the pipe. Of course, in all The consumption of coal, at a low calcuthese arrangements, air must be extract-lation, will be 24 tons a year, which ed by flues or fans, or some other meth- would require 12 carts to convey it to od, so as to ensure a due circulation of the houses—or a street such as Eaton may be in the methods of its application ply it with coal. to warming, and I do not hesitate to say presence of between 2,000 and 3,000 that it can be easily applied so as to be horses, and each horse causes, by the hygienically perfect in that respect; manure it deposits in the streets, an moreover, you can apply your heat at the additional pollution of our atmosphere. exact point at which you want it, for you When the coal is placed in the house, can so arrange it as to give out a low de-these 24 tons require to be carried up in gree of heat for warming fresh inflowing coal-scuttles, each holding probably a air, or to give out heat to warm your quarter of a hundredweight. That is to dados and prevent your own body losing say, that there would have to be carried has only to be carefully adjusted to pro-probably to the extent of 400 coals-cuttles,

You can turn it off when you leave your room and turn it on again when you reoften becomes oppressive. Let us consider for a few minutes what is the meaning of revolutionizing the methods of warming our houses in the way I now propose. We should not load our atmosphere Mr. cally pushed up out at the top of the A gas burner is placed at the These inconveniences result from having each separate object. Let us consider, But, however advantageous gas Place would require 12.000 carts to sup-These carts entail the its natural heat too rapidly by radiation; from the cellar to various parts of the or you can use it to give out a high de- house nearly 2,000 coal-scuttles full of gree of heat, and thus to furnish radiant coal. The residue would have to be carheat to warm you by direct radiation. It ried down again in the shape of ashes, duce all these advantages, yet there is independently of the proportion of ashes this enormous drawback to its use. At which get scattered from the fireplace the price of 3s. 6d. a 1,000 cubic feet, it about the room, and have to be cleaned would cost to effect these things about up by the housemaid. In addition to four times the price of coal. I believe this, the dirt engendered by the smoke that if it could be supplied so as not to and soot sent up into the atmosphere exceed double the price of coal, it might renders much additional cleaning necesbe economical to use it, because you can sary, and entails on the inhabitants of waste of fuel. way.

But it is not on the ground of economy would not pollute our atmosphere.

London a vast expenditure on soap, and that I advocate a change. It is on the on repainting and redecorating our rooms. ground of purity of air. So long as we Indeed, the late Miss Garrett, who was celebrated for her skill and taste as a outside air impure, but the air is so loaddecorator of houses, told me she had no ed with dirt that the careful householder sympathy with the movement for the excludes it from his rooms where posabatement of smoke, because she looked sible. You would all be ashamed to supupon smoke and fog as specially sent by Providence for the benefit of decorators. Upon your guests at a party with bad Providence for the benefit of decorators. The labor thus entailed is wasted force. which you ought to be, to supply them It entails vast unnecessary labor and with bad air, we should soon take meas-Probably if the price of ures to build our houses so as to keep up coal had remained high, as it was in a continual flow of fresh air throughout 1875-6, we should ere now have begun to our rooms. And then we should be rapwarm our houses in a more rational idly compelled to take measures also for warming our houses in a way which

DRAINAGE OF LARGE MARSHES.

BY C. E. HOLLISTER, OF LAINSBURG.

Transactions of the Michigan Association of Surveyors and Civil Engineers.

nor in the ease and manner of their and swamps. drainage. Those lying nearly level with resorting to such an expensive process, and we will therefore omit all this class neer of the future.

The northern part of this peninsula was probably once an island, separated from the main land by a broad strait, extending from Saginaw Bay westerly through the region now known as the country between the Saginaw and Grand of say 20 feet in width. lowest point in the water-shed dividing mon proceedings under the drain law. the eastern and western slopes of the State. As this region is some 80 or 90 miles from either Lake Huron or Michigan, the water-courses have little slope, their course, at a moderate stage, no fall in the surface of the water for one or several consecutive miles, and at other

Marshes are not alike in all features, many a needless mile through marshes

Either the river channel must be deepthe great lakes would probably have to ened or the banks leveed and the marshes be diked and pumped out. But land in drained by pumping. Fortunately the Michigan is as yet too cheap to warrant former is much the cheaper in first cost, to say nothing of maintenance.

The problem in such cases is not so of swamps, and leave them to the engi- much what to do or how to do it, as it is to raise the necessary funds for the work. The present owners are not rich; had they been they would have bought upland; they have no idea that the land will be worth anything if drained, and the work requires a large expenditure all Saginaw and Grand River Valleys. This along the line, to which they will never portion of Michigan is still low, and the agree except in the case of small streams Rivers, in Gratiot County, is perhaps the streams require some other than the com-

It needs no argument nor any unusual experience to set forth the unhealthfulness of this state of repeated overflow and evaporation under the summer sun. actually showing at some portions of But it seems that argument and facts and long continued agitation may be necessary to convince the people of the State that they can afford to deepen these times having for 10, 15, or 20 miles no river channels, and that a just consideramore than 10 to 14 inches fall per mile. tion for the health and lives of those Their channels are very tortuous, with living near such streams will warrant

the expenditure and demands the assist- Maple River to Cedar Lake is about 95 ance of the State in aiding and urging on feet. this work.

In two noteworthy instances, the deepening and straightening of small streams preparatory to draining the large areas of wet land along their courses have been begun and carried nearly to com- it was necessary to increase the depth drain law, J. N. Smith as County Drain tract in August, 1882, and most of the Commissioner planning and directing the work. The South Maple, or south pond on sec. 16, T. 6 N., R. 1. W.; finds its way without much channel in a southerly direction through wide marshes for about 2 miles, then makes a sweep east of acres of wet land which is assessed for and then northerly to the Maple River benefit is about 3,300, making the cost on section 4 of T. 7 N., R. 1. W. At the point where it turns east it is about 1 mile from the Looking-glass River, which at that point flows west in wide marshes.

Marsh land extends continuously from the creek to the river and drains into both. It is a noteworthy fact that, if stream comes from its running north and the creek is cut to the depth of 5 feet towards the low part of the State menfrom the surface of the marsh and a tioned before. The Cedar River empties branch extended to the Looking-glass into the Grand at Lansing, the Looking-River, it will bring water from the changlass at Portland, and the Maple at into Maple River. about one-third of the Town of Victor, west of the meridian, we find the Cedar and about half of Ovid Township. bottom or swale only a few rods wide; low the Looking-glass. but most of the way through marshes or line being about 17 miles long, and havabout 2 miles long, laid out and dug at them. the same time.

to 8 feet. stream is another branch of some miles half a mile. in length. point about 4 miles further up stream less it will settle. another branch comes in, and the width In making our calculations, we must, beyond is again reduced to 2 feet on the to save expense, go no farther down the om.

It was proposed to make the bottom of drain 4 feet below the surface of the water at the stage when the preliminary survey was made, but the square mile of marsh that drains into it lies so flat that pletion in Clinton County, under the to 5 feet. The work was put under conwork was done by Jan. 1, 1883. The people along the line were amazed at the branch of the Maple, has its source in a idea of going so deep, and thought it unnecessary; now they wish the ditch was deeper.

> The cost was \$13,000, and the number about \$4 per acre were it all to come from this land. About \$3,000, however, were assessed to the two towns through which it ran, for benefit to health and highway benefits.

The very remarkable fall in this nel of the latter river through the creek Lyons. All rise near together and flow The creek drains nearly west. If then we cross a little In about 25 feet higher than the Lookingsome places it flows through a narrow glass, and the Maple about 120 feet be-

We find still another class of marshes, elm swamps ½ to ½ mile wide, the main such as the Chandler Marsh—large, flat; no creek flowing through them, but usuing two branches, one about 4, the other ally a creek leading from or heading in Usually the outlet is level for a long distance, so that we have a flat per-From the mouth of the creek, for a haps 4 or 5 miles long, sometimes double distance of 5 miles, the bottom as dug is that, and we find that a large expense to be 12 feet wide, and is to be deepened must be incurred in opening an outlet gradually as the valley widens until a before we can begin to drain the marsh. depth of 5 feet from the surface is at- When the water is drawn out, such tained. At this point the drainage of marshes will settle from 1 to 2 feet. The about a square mile of marsh and the Chandler Marsh has settled so that large adjacent highlands enters the creek. stones project a foot, where in a natural Above this place the bottom is narrowed state, all was water and soft mud, and no About four miles up the one thought of finding a stone within The farther down the Here again the width at the stream from the marsh, the shallower is bottom is contracted to 4 feet. At a the muck, the firmer the ground, and the

The whole elevation from stream than necessary; we must lay the

equally important matters, and have spoiled the job, making it necessary to go all over the same work time and again. Yet if we know and state just what is necessary, we often cannot get our plans adopted, because they look too large.

1. We must allow for the settlement of such marshes and the derangement of our grade. Hence we must cut deeper below and go farther down stream than at first seems necessary. All fail here.

2. We must go deep enough to allow the marsh to settle and still be able to drain the further edges of the marsh to a depth of 3 feet with a proper grade to the outlet.

3. The outlet must be large enough to carry the water off freely. We must look up the local water-sheds and see how much water we have to provide an

outlet for.

The Perrin Marsh, in the town of Greenbush, Clinton County, is a case in point. For some years they raised quite good crops on the marsh, until the neighbors saw that marshes could be made productive, and had ditches dug running back 1 or 2 miles on each side, but especially on the south. As this is south of the low part of the peninsula, the surface slopes rapidly to the north. These side ditches have a great fall, and flood the marsh by bringing the water in too fast for outlet to carry it off. It also was not dug far enough down the stream. South of St. Johns is a similar case which fails for both these reasons, so that the man who was really the pioneer in reclaiming the marsh is completely drowned out and has lost his entire crop for two years on land where, before that time, he had raised most spring crops, hay and onions.

The Chandler Marsh also has no out-The main ditch stands full of water, as any of you who cross it on the J. L. & S. R. R. may see. Of course nothing can be done with land when the had occasion to run the levels again, and water stands in the ditches at a level

with the surface.

grade as flat as will work well, and go no draining them. It is that which flows deeper than necessary. Conditions have on from the surrounding and higher operated so powerfully upon parties in lands, and also that which passes through charge of such works, in all the cases the soil from the uplands, whether it which have come to my knowledge, as to comes in the form of springs or by an alover-shadow other less obvious but most imperceptible soaking through the soil. If we run a branch on each side of the large marshes, we shall cut off all this water which comes from the sides. Otherwise it will flow over the surface and keep the whole marsh wet. This water may be drawn in by laterals, and, in small marshes, with but narrow watersheds on the sides, this is the wiser course, but where a wide marsh is surrounded by a wide strip of flat land, we shall succeed better if we run near the edges of the marsh, and drain from each side of each ditch with laterals.

Some will object to this view, and say that the middle of the marsh will settle most, and hence be too low to drain into the side ditches. In fact, however, the middle of a marsh is generally the highest, and can settle most and yet not be too low; but the main reason after all is, there must be a drain along each edge to catch the soakage, or we shall not have it drained; and the cost will be less than to first make a main through the middle, and then laterals and shore drains. If the marsh is wide, the length of the laterals to bring in the shore water, especially if branch drains are needed as often as one in 40 rods, will be greater than the excess of the shore lines over a main in the center.

DISCUSSION.

Mr. J. J. Watkins did not believe that the bottom of a ditch settles; can see no reason for it, and his experience has proved that the top settles and the bottom rises, so that the ditch gets shallower from two causes. Use an S-rod tape, and give distance in rods and links; commissioners liked it better.

Mr. S. N. Beden was certain Mr. Holland was correct; had tested the bottom many times by reference to a fixed bench mark; in one case when the levels had first been run by another party, and ditch constructed from these levels, he found a perfect agreement with the first levels on hard land, but on the marsh the The water which falls on a marsh is not result showed either an error of the first that which makes the greatest trouble in party, or that the ditch had settled 12 to

14 inches; believed that the bottom of the ditch had settled; put grade stakes down to grade; there can be no mistake, and they remain in the ditch to show the position of the bottom for all time; get them down by driving with a sledge on a turned and graduated hickory stick, with ferule to prevent splitting; no difficulty in getting them down 4 or 5 feet; consider a grade of 1.6 feet per mile as small as should be used; object to less than .06 foot per 100 feet.

Mr. W. B. Sears thought a better plan was to leave the top of each grade stake

3 or 4 feet above the grade line.

Mr. M. W. Bullock would like to know of a small dredge for such work; has had much difficulty with a floating bog; finally conquered it by constructing a flume in sections and sinking each one to place; prefer to drain small marshes by a center ditch.

Mr. B. F. Welles said that underneath the City of Marshall was a layer of sandstone so porous and dry that it would serve as an outlet to marshes if connected. In one case 10 drive wells in an area of 10 acres removed 10 inches of water in two days.

Mr. Hodgman—In some cases drive wells let water up instead of down; it depends entirely on the underlying strata. Many are dissatisfied with drainage because it is only half done; drainage might as well not be commenced as to be only half completed; had seen drains with a large volume of water work well on a level; get all the fall possible; thought that in marshes underlaid with clay the bottom would rise, and in deep muck marshes it would settle.

Mr. W. Appleton thought that the well method of drainage would always work if the well was made deep enough; had tried it with good success himself, and the well worked well for four or five years; he filled the well with small stone, but in time the silt from the marsh washed among them and ruined the well by filling the pores.

Professor J. B. Davis suggested that the well be made large, and that it be made deep enough, so that it should extend some distance into the water taking strata so as to get a side outlet; a settling well or basin should first receive the water and discharge from its upper surface into the drainage well.

Mr. T. W. Petter generally set stakes once in 20 rods, some commissioners prefer a grade table to a profile; must one be made? (The law requires one.)

Mr. C. E. Hollister believes in putting the drains on the edge of the marshes and not through the center; the water that does the injury comes almost invariably from the upland; would have them far enough from the edge of the marsh to allow the velocity of the water from the banks to be checked sufficiently to deposit debris before reaching the ditch. Clinton County has spent about \$60,-000 on county ditches the past year, but the principal construction has been done by hand. The cost for a ditch with an average depth of 5 feet, bottom width 8 feet, top width 24 feet, has been \$5 per The best results were obtained when each man could be induced to take the contract on his own land; had much difficulty with floating bogs. It is impossible to dig them out, when soaked with water; have had good success in freezing weather, by digging but little faster than the muck would freeze; the least grade depends on volume of water; for ordinary ditches should be 1 ft. per mile.

N ABORIGINAL DWELLING.—A short time ago there was discovered in a marsh at Schussenried, in Wurtemburg, a well-preserved hut of the age of stone. The flooring and a part of the walls were intact, and, as appeared from a careful admeasurement, had formed, when complete, a rectangle, 10 meters long and 7 meters wide. The hut was divided into two compartments, communicating with each other by a foot-bridge made of three girders. The single door, looking towards the south, was a meter wide, and opened into a room 6.50 meters long and 4 meters wide. In one corner lay a heap of stones, which had apparently formed the fireplace. This room was the kitchen, "the living room," and probably a night refuge for the cattle in cold weather. The second room, which had no opening outside, measured 6.50 meters long and five meters wide, and was, no doubt, used as the family bedchamber. The floors of both rooms were formed of round logs and the walls of split logs. This, be it remembered, was a hut of the Stone Age. It may be safely presumed that the lake dwellings of the Bronze Age were larger in size and less primitive in their arrangements. At both periods the platform supporting the houses communicated with the shore by means of a bridge (probably removable at pleasure) and with the water by ladders. These ladders, as appears from an example found at Chavannes, were made of a single stang with holes for the staves, which protruded on either side.—Contemporary Review.

LIGHTHOUSE ILLUMINANTS.

From the "English Mechanic."

appliances, and to report upon their relative merits, with special reference to their adaptability for lighthouse purposes. This committee, it will be remembered, was dissolved last year, for reasons which were publicly stated at the time, without having effected any practical work. The Board of Trade, however, subsequently afforded the Corporation of the Trinity House the opportunity of undertaking the investigation, and eventually intrusted the carrying out of the necessary experiments to the Elder Brethren. Thereupon a committee of the Elder Brethren was formed, which consists of the following members:—Captain Sydney Webb (Deputy Master of the Corporation of the Trinity House), chairman; Captain Nisbet, Captain Weller, Captain Burne, Captain Vyvyan, Admiral Sir Leopold McClintock, and Mr. Inglis, the secretary to the Corporation. Mr. Price Edwards, who was the secretary to the previous committee, acts in a similar capacity with regard to the present one. Sir James Douglas, the engineer to the Corporation, is advising the committee on points of detail, and the photometric observations are intrusted to Mr. Harold Dixon, Mr. Vernon Harcourt, F.R.S., is watching the experiments on behalf of the Board of Trade. The Corporation of the Trinity House is acting in conjunction with the Scotch and Irish Lighthouse Boards, and the representatives of various foreign Governments are taking an active interest in the experiments, which, we need hardly observe, promise in their results to prove from a Cornish boiler 15 ft. long by 6 ft. of the highest importance to the mari- diameter, and of which there are two, one time nations of the whole world.

the new committee took the necessary drive the four Holmes machines, and initiatory steps towards carrying out an those used in the experiments to which ments with three available illuminants— mention that upon our recent visit we oil, gas and electricity. To this end they found a very important permanent addiselected the South Foreland for the scene tion was being made to the South Foreof operations, as being the most convelland establishment. This consists of a

The great practical advances made of nient and advantageous for the purpose. late years in the various systems of il- There are already two lighthouses there, lumination led to the appointment of a known as the high and low lights, which committee to investigate the most modern are illuminated by electricity. By the forethought of the Trinity House engineer a surplus of engine power was provided at starting, and is available for the present electrical experiments. Then the surrounding country, being comparatively flat, or only slightly undulating, and the view unimpeded by trees or hedges, renders it a most eligible spot for taking observations far and near.

It is worthy of note that the South Foreland lighthouses, which were originally illuminated by means of coal fires, were the first in which electricity—carbon in a more refined and more highly intensified form—was adopted as an illuminant. This was in 1857, when Professor Holmes first submitted his system of lighthouse illumination by electricity to the Trinity House, and received permission to establish his apparatus in the high light, the system being afterwards extended to the low light. England was thus the first to adopt electricity for lighthouse illumination. The machinery and apparatus used for these two lights consist of four of Professor Holmes' magneto-electric machines—two for the high and two for the low light-which are both powerful and safe, producing a low tension current not exceeding 60 volts. They are, moreover, very reliable, costing little or nothing for repair. There are two horizontal steam engines of the single-cylinder type by Messrs. Hunter and English, each of 10 horse power nominal, but capable of developing 30 horse power each. Steam is supplied being kept in reserve, as is also one of Immediately upon their appointment the engines, a single engine sufficing to elaborate and exhaustive series of experi- we shall presently refer. And here we may long one-storied brick building which is being erected by the Trinity Board for the purpose of conducting photometric experiments with very powerful lights, for which at present there exist no adequate means. This shed is 380 feet in length, and it will be fitted with the necessary appliances for light testing, and there in future all the large lights will be tested.

In connection with the experiments three temporary wooden towers have been constructed in a line landwards and bearing north-west from the permanent high light. These towers are marked A, B, and C, and are respectively used for the electric, the gas, and the oil light. Tower A is 245 feet from the high light, and tower B 180 feet from A; tower C being the same distance from B. focal plane of all the towers is 15 feet below that of the electric high light, which lamps and magneto-electric machines are these lamps and two of the machines in place, but another of each is to be added. carbons used in them are compound that is, they are made up of a number of small carbon rods of square section. The carbons in use at the time of our visit were 1½ inches square, and were composed of 49 small square rods, but since then the new Berlin Code carbons of The two machines for producing the curthe others, and, as we have stated, are machines. Each of the De Meritens machines is arranged for working at onefifth, two-fifths, three-fifths, and at fullpower, the estimated intensity of the light from each machine at those powers being respectively 6,000, 12,000, 18,000, either be worked singly or coupled up.

having been adopted for lighthouses on the Irish coast. The gasworks were put up and the gas illumination is now being carried out under Mr. Wigham's supervi-The gas-producing apparatus consion. sists of a small retort house fitted with two benches of three retorts, the necessary purifiers, and a holder capable of containing 4,500 cubic feet of gas. The gas is passed through a meter placed outside the tower to the burners within it, and which are four in number. Each burner is composed of a series of concentric rings of jets, and the light can be started with a minimum power of 28 jets, and increased by gradations of 20 jets up to 108 jets, the full power of each burner, at which it develops 3,000 candle power. There are four of these burners superposed, and they can be used either singly or together, the lights being designated uniform, biform, triform, and quadriform, is 380 feet above sea level. In the elec-according to the number of burners in tric arrangements Baron de Meritens' arc use at the same time. The object of the variations of power in the lights in all employed. At present there are two of cases is to meet the varying requirements

of the atmosphere.

In tower C, oil lights are used, and The lamps are placed one above the these are produced by means of burners other, or superposed, in the tower. The of the recognized Trinity House pattern. For this purpose nothing further is necessary than a tank outside the tower containing a store of Scotch paraffine and the lamps and burners in the tower. The oil is supplied to the burner from the lamp under slight pressure by means of an arrangement similar to that adopted Messrs. Siemens have been employed in obtaining hydraulic power, oil, of course, taking the place of water. The rent are placed in the engine house with burners at present in use have six concentric wicks, each burner developing driven by the same engine as the Holmes | 720 candle power; but Sir James Douglas is preparing another burner of much higher power, having seven wicks, which will shortly be tried. The burners are arranged in three stages, and either a uniform, a biform, or a triform light can be exhibited as required. The burners and 30,000 candles. The machines can are in duplicate on each stage, and by an ingenious arrangement the first lamp can Like the Holmes machines, those of De be shunted out of position if necessary, Meritens produce a low tension current, and the second one lighted and shunted and are found to be very reliable in oper-into its place without any appreciable ation and inexpensive in maintenance. loss of time. Sir James Douglas has The arrangements for illuminating tower also devised a very simple but effective B consist of a small gasworks erected by arrangement for ventilating lighthouses Mr. J. R. Wigham, of Dublin, whose by means of which the heated air is carried burners are used in the tower, his system rapidly off, but the atmosphere of the

lighthouse is kept perfectly steady to a quarters at St. Margaret's, contiguous to very high elevation in the coned roof, as tower.

Such are the arrangements for producing the various lights. For testing them, carefully elaborated arrangements have been made. An overland route has been laid down as a line of observation for a the direction of Deal, and stakes have been driven at every 100 ft. At half a mile from the towers on this route is hut No. 1 for taking photometric observations, and this is more particularly intended for fog work. At $1\frac{1}{4}$ mile we come upon hut No. 2, which is likewise fitted with photometric apparatus. At the limit of the range is the third hut, each hut being conveniently fitted up for the residence of the official in charge. Arrangements have also been made for observations to be taken at the various coastguard stations within the focal area, at Ramsgate and other contiguous places, and at various points out at sea, including the Gull and Varne light vessels, which are respectively 8 miles N.E., and 12 miles S. and their contents collated for the information of the committee. of South Foreland. The committee have maritime nation.

the experimental towers, where one of was shown by experiments in this their body will always be in residence. Ranging over so wide an area as they will, and involving so many investigations as they do, we need hardly say that the experiments will occupy several months, probably five or six. Every illuminant and variety of burner adapted for lightdistance of $2\frac{1}{2}$ miles from the towers in bouse illumination will be tested under every possible condition pertaining to itself and to the atmosphere. The most important point as regards atmospheric conditions will be fogs, which will have very careful consideration. occasion of our recent visit splendid lights of varying intensities were produced at night by each of the three systems under trial. The preliminary photometric observations appear to indicate that the electric light in comparison with either the gas or the oil light is as the sun is to a candle. This, however, is but natural, but, as a result, it has to be considered in connection with a variety of other conditions into which it is not only unnecessary, but inexpedient for us to enter. The experiments have at first W. distant from South Foreland. The been confined to the testing of apparatus observers are supplied with books for and contrivances already in use. A furrecording their observations in tabular ther stage will be devoted to any other form, which will ultimately be collected burners and appliances which shall be submitted to the committee, and after The books inspection by them shall be adjudged contain directions as to the method of suitable for lighthouse illumination. It procedure in making observations. Ob- is thus open to the whole world to assist servers are also provided with charts for in promoting a movement of the first land and sea observations, showing the importance, which in its results cannot illuminated areas to the north and south fail to prove of the highest value to every

THE SOFTENING OF WATER.*

BY BALDWIN LATHAM, M. Inst. C.E., F.G.S.

From "The Building News."

From the remotest period of antiquity, produced until sufficient soap has been the art of softening water for the pur- used as to soften the water. For the purposes of washing and cleansing appears poses of this investigation water may be to have been known and adopted. Soap divided into two classes, hard and soft. is very largely used, or rather wasted, in Hard water is a water which contains many places in the present day for soften- salts of lime, magnesia or iron, and someing water, for which it is now well under-times an amount of free carbonic acid. stood that no useful effect in washing is A hard water is one that destroys soap in washing, while a soft water is one that *A paper read at the Society of Arts Water Supply does not destroy soap. A soft water

may derive its properties from an absence those of soda, may be quite unfit for of earthy salts, or it may have become drinking purposes. A type of this water soft by reason of the presence of certain is found in the well supplying the Traalkaline salts in the water, notably the falgar square fountains, as it is stated salts of soda and potash. Hard waters that the large amount of soda contained may be divided into two classes, those in it, if taken habitually, acts medicinally which are permanently hard and those upon the kidneys. It is also unfit for which are temporarily hard. Generally a single sample of naturally hard water partakes of both these properties. A water which is said to be temporarily hard becomes soft by boiling, as the hardness is due to salts of magnesia or lime dissolved in the water by the agency of carbonic acid, or due to the presence of this gas in a free state in the water. Under either circumstances the effect of boiling the water a sufficiently long time is to drive off the carbonic acid gas, and a natural softening of the water takes place from the absence of this gas, and the earthy salts that have been held in solution by it in the water. Water that is perfectly hard derives this property from the presence of the same salts as are in water temporarily hard, but instead of being combined with carbonic acid they are combined with sulphuric acid, and to soften water that is permanently hard requires very different conditions than is the case with waters that are only temporarily hard. The qualities of a good drinking water have been described as: 1st. Freedom from vegetable and animal matter. 2d. Pure aëration. 3d, Softness. 4th. Freedom from earthy, mineral or other foreign matter. 5th. Coolness and delivery at the minimum temperature. 6th. Lucidity or clearness. 7th. Absence of taste and smell. Although many authorities insist that for the sake of health a soft water is beneficial, on the other hand, there are those who contend that there is no evidence whatever to show that even a hard water has any influence upon health. It is clear, so far as of danger, and always of expense. the health statistics of this country are The effect of boiling water in order to concerned, that, if anything, the results soften it can only be secured when this come in favor of persons inhabiting dis-operation is sufficiently prolonged. The tricts having hard waters. On the other commissioners appointed to inquire into hand, it has been thought that particular the chemical properties of the water of diseases which affect particular localities, the metropolis in 1851, made some exsuch as cretinism and goitre, are due to periments on the effects of boiling an articertain salts of magnesia which have been ficially prepared hot water containing found in the waters of the district. Some 13.5 grains of carbonate of lime per galwaters which are of remarkable softness, lon, and it was found to decrease in hardin which the softness is due to the presences from 13.5° to 11.2° by being heated

washing, as the water is liable to destroy certain colors and stains glass. is said to be unfit for bathing, as the soda combines with the oily matter of the skin, producing a roughness and liability to chapping. Water, however, which is naturally soft, or which has been softened by means of a process like Dr. Clark's, which does not add any new element to the water, has great advantages for many purposes. It prevents incrustation of steam boilers and household utensils, it results in a saving of fuel, less wear and tear in washing linen, and in the labor of cleansing; it saves soap in all washing and cleansing operations, the water cleans better, and gives a better color to linen, and it is also stated to lead to greater economy in tea-making and brewing, but whether this is correct or not is very doubtful, as water used for such purposes is always boiled, and when used in that state should be as soft as softened The processes which have been used both in ancient and modern times, may be comprised under the heads of boiling, chemical processes, distilling, exposure, freezing.

SOFTENING BY BOILING.

The effect of boiling water is to liberate the carbonic acid which holds certain alkaline salts in solution, and on the liberation of the acid these salts are precipitated, and form the coating which furs our kettles, accumulates in our boilers, blocks the circulating pipes of our waterheating apparatus, and is often a source ence of certain alkaline salts, especially to the boiling point; after boiling for 5

minutes it was reduced to 6.3°, for fifteen minutes to 4.4°, for thirty minutes to 2.6°, and for one hour to 2.4°, so that the softening effect does not take place at once, but a prolonged boiling is required in order to produce the greatest degree of softening. In order to get rid of the temporary hardness of water, sharp boiling for not less than twenty minutes is requisite, but boiling water does not remove the hardness occasioned by the salts, which are neutral; in fact, the permanent hardness of the water is increased by boiling, as all the water evaporated leaves a concentration of the neutral salts in the remaining water. It has also been shown that the alkalinity of water is more after boiling than when softening has been produced by an alkaline salt, such as lime; but both have the effect of reducing the hardness to about the same degree. This increase of alkalinity after boiling is attributed to the concentration of the neutral salts consequent on the loss by evaporation. The temporary salts held in solution by water are precipitated by boiling, and it is these precipitated salts which cause the furring of kettles, hot-water boilers, steam boilers, and hot-water pipes, and have led to the adoption in certain cases of means either for retaining the salts in solution in the water, or of preventing their deposit in steam boilers, but as a rule with only partial success.

CHEMICAL PROCESSES OF SOFTENING WATER.

In a paper read before the Literary and Philosophical Society of Manchester, in 1781, by Thomas Henry, F. R. S., a description is given of a mode of preserving sea water by means of quick lime, in which the author pointed out that the earthy base of magnesia was precipitated in sea water by lime, and its also referred in this paper to the wellknown action of quicklime on common The effect of water as a preservative. Vol. XXXI.—No. 4—22

country was taken out in 1838, for precipitating by muriate of zinc and salts of soda, the latter salts precipitating the zinc from the water, leaving the water in a purified state. In 1841, Dr. Thomas Clark, of Aberdeen, took out a patent for his well known and beautiful process for softening water, and which has, more or less, been the basis of all other patented processes of this description which have been adopted since that period. Dr. Clark thus described his process in May, 1856:

"In order to explain how the invention operates it will be necessary to glance at the chemical composition and some chemical properties of chalk, for while chalk makes up the great bulk of the matter to be separated, chalk also contains the ingredient that brings about the separation. The invention is a chemical one for expelling chalk by chalk. Chalk, then, consists, for every one pound of sixteen ounces, of lime, nine ounces; carbonic acid, seven ounces. The nine ounces of lime may be obtained apart by burning the chalk, as in a lime kiln. ounces of burnt lime may be dissolved in any quantity of water not less than forty gallons. The solution would be called lime water. During the burning of the chalk to convert it into lime, the seven ounces of carbonic acid are driven off. This acid, when uncombined, is naturally volatile and mild; it is the same substance that forms what has been called soda water when dissolved in water under pressure. Now, so very sparingly soluble in water is chalk by itself that probably upwards of 5,000 gallons would be necessary to dissolve one pound of sixteen ounces; but by combining one pound of chalk in water with seven ounces additional of carbonic acid—that is to say, as much more carbonic acid as place taken by a calcareous salt. He the chalk itself contains—the chalk becomes readily soluble in water, and when so dissolved is called bicarbonate of lime. If the quantity of water containing the the lime, doubtless, upon the sea and one pound of chalk with seven ounces adfresh water was to induce abundant ditional of carbonic acid were 400 galprecipitation, which dragged down with lons, the solution would be a water of it certain organic impurities, and as a the same hardness, as well water from consequence the water remained free the chalk strata, and not sensibly differfrom putrefactive influence afterwards, ent in other respects. Thus it appears as was clearly shown in the course of his that one pound of chalk, scarcely soluble experiments. The first patent for puriat all in water, may be rendered soluble fying water by chemical agency in this in it by either of two distinct chemical

water, and soluble by combining with a bicarbonic of lime. lime water, and another solution of the pounds of chalk, which will, after the the process is fairly set a-going. above. This water will be free from bicarbonate of lime, free from burnt lime, and free from chalk, except a very little, which we keep out of account at present, for the simplicity in this explanation. A small residuum of the chalk always remains not separated by the process. Of $17\frac{1}{2}$ grains, for instance, contained in a gallon of water, only 16 grains would be tate. deposited, and 12 grains would remain. In other words, water with 17½ degrees of hardness arising from chalk can be reduced to $1\frac{1}{2}$ degrees, but not lower. These explanations will make it easy to yellow color will show itself." comprehend the successive parts of the softening process. Supposing it was a delicate test than the silver test, for asmoderate quantity of well water from the chalk strata around the metropolis that we had to soften, say 400 gallons. This quantity, as has already been explained, would contain one pound of chalk, and the presence of alkalies; and other agents would fill a vessel 4ft. square by 4ft. deep. We could take 9 ounces of burnt lime made from soft upper chalk; we first slake it into a hydrate by adding a little water. When this is done we would put the slaked lime into a vessel where we intend to soften water gradually. Add some of the water, in order to form lime water. For this purpose at least 40 gallons are necessary, but we may add water are used, or one grain of chalk in 100,000 gradually until we have added thrice as grains of water, so that it is necessary, much as this; afterwards we may add in considering the reports of the Rivers the water more freely, taking care to Pollution Commissioners, to bear in mind mix intimately the water and the lime this difference of degrees of hardness. water or lime. Or we might previously To reduce the hardness to parts per gallime water instead of lime, putting in the decomposes soap. The amount of soap lime water first and adding the water to ascertained by Dr. Clark to be wasted bebulks of the hard water.

changes: soluble by being deprived en- is, the softening ingredient, be put into tirely of its carbonic acid, when it is the vessel first, and the hard water gradcapable of changing water into lime ually added, because there is thus an excarbonate of lime produced in the process second dose of carbonic acid, making up more easy. But what you will wish to Now, if a solution know now is by what mark is the conof the nine ounces of burnt lime, forming ductor of the process to find out when there is enough of water to take up the one pound of chalk and the seven ounces last of the excess of lime, so as to be of carbonic acid, forming bicarbonate of enough, but no more. This is done by lime be mixed together, they will so act what has been called the silver test, the upon each other as to restore the two only test necessary to the operator after mixture, subside, leaving a bright water test is a solution of nitrate of silver in twice distilled water, in the proportion of an ounce per pint. In making use of the silver test in ordinary water we get a white precipitate; but if the water have in it a notable excess of lime water, there is a light reddish brown precipitate produced; but if the excess be very slight, we only get a very feeble yellow precipi-The way we make use of the test is to let two or three drops of it fall on the bottom of a white tea cup; then add the water somewhat slowly; then, if there be the slightest excess of lime, a

It may be here mentioned that a more certaining if there is an excess of lime in the water, consists in using a solution of cochineal, the natural color of which is yellowish red, which is turned violet in are now used to show, by distinct color. or its absence, if there is an excess or not of lime in the softened water. cording to Dr. Clark's scale, 1° of hardness means that there is one grain of chalk in a gallon of water. According to the scale introduced by Dr. Frankland, in the sixth report of the Rivers Pollution Commissioners, parts per 100,000 form saturated lime water, which is very lon, or to the Clark scale, it is necessary to easy to form, and then make use of this multiply by 7 and divide by 10. Hard water be softened. The proportion in this case fore softening the water is equivalent to would be one bulk of lime water to ten 2 ounces for each degree of hardness for It is of im- every 100 gallons. Dr. Clark introduced portance that the lime or lime water, that a soap test, or a means by which a solu-

Beyond this, lime is not monia. works at Horsham, where the water was the use of this salt.

tion of soap is made to at once indicate water. This was shown by the Rivers the degree of hardness of a water. Pollution Commissioners, and by the an-When pure chalk is burnt into lime, one alysis published by Professor Wanklyn, pound is converted into 9 ounces of lime, especially in the marked diminution and this quantity is soluble in 40 gallons in the amount of albuminoid am-The great objection raised soluble in water, so that clear lime water against soft water has been its liability to always possesses a known composition. produce lead poisoning; but the concen-This amount of lime is equivalent to sus of opinion is that water softened by 98.43 grains per gallon. As one particle the Clark process is not liable to attack of lime will remove $\frac{1.6}{9}$ = 1.77 of chalk, it lead, which is a point of very considerable follows that $98.43 \times 1.777 = 174.9$, or the importance in favor of the process. Dr. number of gallons of water 1° of hardness Clark's process was first carried out by which one gallon of lime water will the Woolwich and Plumstead Watersoften. In practice, however, while theo- works Company, where it was shown retically 175 gallons of water of 1° of that the water was successfully softened hardness may be softened by one gallon from 23° to 7°. These works were subof lime water, owing to the impurities in sequently bought by the Kent Waterthe lime, probably not more than 140 to works Company, and the process of 150 gallons would be softened, so that, softening the water was discontinued. to arrive at the amount of lime water In the course of experiments made in necessary to soften hard water, if we di-softening various waters, it was observed vide 150 by the degrees of hardness act that, if the water was at all tinted, the cording to Clark's scale, it will, gener-softening process did not clear it; but ally, roundly represent the number of there was a tendency for the matters gallons of water which can be softened separated to remain in suspension in by one gallon of lime water. Neither such water, so that it was considered exby boiling nor by the lime process can pedient, in softening river water, that the all the hardness which is termed "tempo- water should be filtered until quite rary hardness" be removed; in fact, a bright before it undergoes the softening small quantity of chalk, to the extent of process. In 1852 a patent was applied one part in 5,000 parts, is insoluble in water, for (W. B. Bowditch) to treat water with and still remains in solution after the clay and alkali, and subsequently filterprocess. In practice, however, 10-11ths ing. Mr. Philip H. Holland, M. R. C. S., of the whole of the temporary hardness late inspector to the Burial Acts Office, may be removed by the lime process. In suggested as an addition to the Clark carrying out the Clark process, the lime process the use of oxalate of ammonia or water is usually applied, owing to the soda to further reduce the hardness of fact that it is a standard liquid contain- the water after treatment by this procing a known quantity of lime, although ess. The use of carbonate of soda for cream of lime is sometimes used with ad- softening water has been known throughvantage. Large tank space is required out the whole country by tea-makers to carry out the Clark process, three from an early period. This salt added to tanks ordinarily being required, one for water acts on the bicarbonate of lime filling up, another for drawing down, and magnesia, and precipitates chalk and a third in reserve while cleansing is and carbonate of magnesia. It also going on, and each tank should hold a decomposes the sulphates of lime day's supply. It is important to know and magnesia, precipitating the lime that the salts of iron may be readily reand magnesia, while the soda remains moved by the application of lime. This in solution, so that the permanent the author found in the case of a water-hardness of the water is reduced by The process. so highly charged with iron that every-thing it touched was discolored; but by the application of lime the whole of the about $4\frac{3}{4}$ times as much soda being reiron was removed. It should also be quired to produce the same results as noted that the process has a marked ef- in the case of lime. An old recipe for fect in removing organic matter from softening water, and useful for some domestic purposes, is as follows: Dissolve 6lbs. of pearlash, or sub-carbonate of soda, in a gallon of soft water, boil the solution, and when boiling add 2ozs. of soap, and stir until all the soap is dissolved. When this solution is added to water to be softened, the carbonate of soda and the soap combining with the salts, producing both temporary and permanent hardness, form an insoluble compound by the combination with the soap, which coagulates and rises to the surface of the water, and may be skimmed As any of the earthy alkaline earths may be used instead of or in addition to, lime, it is not surprising that, since the date of Clark's patent, numerous patents In 1873, the lime process, in conjunction have been taken out for softening and purifying water in which lime, in com- was patented; also lime, carbonate of bination with other alkaline earths, have been proposed. For example, in 1849 Mr. John Horsley took out a patent for the use of calcined or caustic barytes, phosphate of soda, oxalic acid, or preparations of these substances. In 1850, lime, in combination with chloride of barium was patented. In 1852, hydrate of was patented. In 1876, the lime process potash and hydrate of soda, clay and all in combination with filter presses was kalies were the subjects of separate patents. In 1853 and 1854, hydrate of barytes and hydrate of strontia formed the subject of patents. In 1855 a patent was taken out for a powder containing oxalate of ammonia, peroxide of manganese, and charcoal. In 1856, silicate of soda, in combination with carbonate of carbonate of soda with the lime process, soda, was patented. In 1856, bicarbonate of soda and oxalic acid, in crystals, In 1879, Mr. Porter took out an addiwere again proposed to be used. In 1856 and 1857, carbonic acid was proposed to be introduced in conjunction In the same year phosphoric acid and with hydrate of lime. In 1860, bicarbon-phosphate of lime were proposed as a ate of soda and silicate of soda were means of softening water. In 1880, the again twice patented. In 1862 the ordimeans of automatically carrying out the nary lime process was repatented. In softening process, and adjusting the 1863 the use of chloride of barium was qualities by means of an arrangement of patented. In 1865, hypermanganate of ball valves in a cistern, was patented. In potash, carbonate of soda, alum and 1881, Mr. Porter took out a further neutralized aluminite, or a solution patent for the automatic regulation of the of iron was proposed; and in another pat-supply of the solution of lime. In 1881, ent, sesqui-sulphate of alumina was pro- Mr. Atkins took out a patent for treating posed as a means of purifying water. In water with lime, and subsequently filteranother patent, taken out in 1865, the use of soda and lime is again patented. In 1882, an apparatus for softening and In 1866 a patent was taken out by a clarifying water was proposed, in which Mr. J. W. Tobin for an improvement on sloping shelves in a vertical vessel were the Clark process for mixing the lime used, the water entering the bottom of and filtering. In 1866 the use of chlo- the vessel and flowing off at the top; or

rine and permanganates, in combination with any alkaline earth, was patented. In 1867 a patent was taken out for a preparation in a portable form, consisting of marshmallow, linseed, bran, starch, gum, or any softening ingredient, for the purpose of softening water for ablution purposes. In 1868, the use of barytes was again patented, and the precipitate removed in vessels of a cellular form. 1869, the use of steam applied to water as a means of softening it was patented, the particles subsiding on shelves arranged in a vertical vessel. In 1872, unslaked lime and sulphate of soda were patented as a means of purifying water. with a mixing and filtering arrangement, soda, chloride of barium, or other reagent in conjunction with filtering. In 1874, the treating of water with lime and carbonate of soda in combination with filtration was proposed. In 1875, the lime process, pure and simple, and in combination with other reagents and filtering, first patented by Mr. Porter. In 1877, the use of oxide of magnesia and basic carbonate of magnesia was proposed; also the use of a carbonate of potassa, silicate of soda and niter cake, used separately or combined. In 1878, a patent was taken out for combining biand filtering upon the Porter-Clark plan. tional patent for carrying out automatically the softening and purifying of water.

to another might also be used with the same object. In 1883, Messrs. Gaillet and Huet's apparatus for softening water was patented, consisting of sloping and V-shaped shelves in a vertical vessel, the water entering at the bottom and flowing was also taken out for the use of phosphate of soda, and an apparatus for measuring the water and lime to be used in the softening process.

MODERN INVENTIONS FOR SOFTENING WATER.

The modern inventions for carrying out the Clark process may be described as the application of machinery to the saving of time, space and labor. those in general use, dealing with them in the order of date, the Porter-Clark process comes first. In the ordinary Clark process, lime water, in known quantity, is first admitted into a tank, to which the water to be softened is added. However, in some cases, the lime water and the hard water are allowed to flow in together into the tank, but it was considered by Dr. Clark to be an advantage, in carrying out this process, for the hard water to be brought into contact with an excess of lime water in the first instance, which was led into the tank before the water to be softened was added. In the ordinary Clark process, not less than 16 hours were required for the softening and subsidence of the matters separated from the softened water. In the Porter-Clark process, instead of allowing the particles of carbonate of lime to separate and subside, a brisk agitation is maintained, so that these particles remain in suspension, so as to permit chemical reaction with the lime, and the purification of the hard water which, when completed, is passed onward to filter presses, where the carbonate of lime adheres to the filtering cloth. The subsequent operations of filtering through the deposit on the cloth then takes place, and the water is passed away at once in fit state for use, so that the process is continuous in its action, and may be carried on just as quickly as water may be pumped from a well, provided the apparatus is of suffi-

concentric cylinders overflowing from one in this case is passed through horizontal cylinders, which are termed lime churns, and is constantly churned up with water, and the lime water so made is, by suitable arrangements, allowed to mix with the ordinary water in proper proportions, after which it is again agitated. Mr. out at the top. The use of steam and Porter has also an apparatus by which, caustic soda was also patented. A patent instead of using ordinary filter presses, he can use filter frames, and where power is not available, he also suggests a means of working the process without such power. In some cases the power obtained from the pressure of the water is utilized for working the apparatus. apparatus of this description may be seen at the Camden Town locomotive sheds of the London and North-Western Railway, and the apparatus may also be seen at work within the Health Exhibition.

THE ATKINS PROCESS

Is also a modification of the Clark process, by which the space formerly required is reduced. The lime is put into a vessel where lime water is formed, and this water is allowed to mix in its proper proportion with the water to be softened in a specially-arranged mixing vessel, after which it passes into a reservoir of small dimensions. From this reservoir it is conveyed to filtering vessels which contain a special arrangement of filter, consisting of a series of chambers mounted upon a central hollow shaft, these disc chambers being covered with prepared canvas, upon which the deposit of chalk, &c., adheres, and through which the softened water filters. The filters are cleansed by means of revolving brushes. The apparatus does not require power to maintain it while at work, the only power used being that necessary to give motion to the brushes when the apparatus is cleansed. The system may be seen at work at the Henley-on-Thames Waterworks, and at other places.

IN THE PROCESS OF M. MAIGNEN

A powder is used which the inventor calls "Anti-calcaire." This powder is made of variable composition in order to suit the special characteristics of the water to be treated, the ingredients used for ordinary hard water being lime, soda cient capacity to allow time for the water and alum in suitable proportions. In to remain in contact with the lime in the apparatus, which is at work at the passing through the machine. The lime International Health Exhibition for softening water for some of the breeding tanks, the water entering the apparatus gives motion to a water-wheel, which in its turn works an arrangement for distributing a given quantity of the softening agent, and causing it to pass into the water. The water is then allowed to subside in a small tank, and is eventually filtered through filters covered with asbestos cloth, the basis of the filter being similar to that of the "Filter Ra-A part of the carbonate of lime and magnesia deposited from the water adheres to the filtering surface, and the softened water filters through it. The apparatus may be seen at work in the Exhibition.

THE PROCESS OF MESSRS. GAILLET AND HUET.

In this process, patented in February, 1883, the patentees make use of certain known agents, the patent itself applying to the apparatus used for the purpose of producing the results after the chemicals have been applied. The agents they propose are lime and caustic soda. Whenever the water contains organic matter, they use salt of alumina or iron in addition. Iron, however, is not recommended in any case where the water is required for washing purposes. The apparatus consists, virtually, of a series of tanks in duplicate, in which the chemicals are mixed, and these enter a vertical pipe in proper proportion to the water to be softened, and which communicates with the bottom of an upright chamber divided by a series of sloping shelves through which the water gradually works up in a zig-zag path. shelves slope in one direction and are of V-shape, so that as the deposit takes place it accumulates at one point, at which there is an opening ordinarily closed by a tap, and when any tap is open the deposit on the sloping shelf communicating with it is washed out. apparatus appears to be extremely simple in its design, but its efficiency has yet to be tested, although it is at work at Messrs. Duncan's, Victoria Docks.

PURIFICATION BY DISTILLING.

Purifying water by the process of distillation has been used from remote periods in order to produce absolutely pure water, and during the last forty years very great improvements have

process into more general application in connection with the purposes of water supply. The difficulty of obtaining absolutely pure water is practically exemplified by this process, for in attaining this result, unless the water is distilled some two or three times, and every time a large proportion of the residue is discarded, pure water cannot be obtained. In the case, however, of water distilled for dietetic purposes, it is not necessary to carry out the process to the extent required in procuring water for some chemical purposes. It has generally been considered that distilled water lacks aeration, and on this account it has been strongly recommended that it should be filtered. The great improvements in the processes of distillation are due to Dr. Normandy, whose first patent, taken out in 1851, has been improved upon by many subsequent patents. The process has been adopted with the greatest advantage in many of our ocean steamers, and the preservation of the health of the crews and passengers visiting countries liable to the ravages of epidemic disease is, in great measure, due to this process. It is generally believed by many high sanitary authorities that if this system were adopted at malarious stations, one of the largest channels by which infection is disseminated would be effectually closed.

SOFTENING BY EXPOSURE.

The exposure to the air of water containing salts which are held by carbonic acid causes a loss of carbonic acid. Water of deep wells which has been in contact with chalk and other rocks often contains free carbonic acid by exposure, especially under the inequalities of diurnal temperature, the original charge of ground air is got rid of, and atmospheric air takes On exposure to air, hard its place. waters are especially liable to develop vegetable growth. A few days' exposure of very hard water in the summer time will soon develop green confervoid growth, and so soon as this growth takes place, carbonic acid is rapidly used up by it, so that the bicarbonates in the water are soon converted into simple carbonates, and are precipitated. Water, therefore, exposed to air undergoes a chemical metamorphosis; the bicarbonates of lime been adopted in order to bring this and magnesia are converted into carbonates, and are precipitated, and it is in this way that exposure assists in softening water.

SOFTENING BY FREEZING.

Ice taken from hard or other impure waters, if found to be perfectly crystalline and free from air bubbles, will produce, on melting, a water as soft as that of distilled water. If, however, the ice contains air bubbles or cavities of any description, such water will not be entirely pure. Some years ago the author made an extensive series of experiments upon the degree of purity which might be arrived at by freezing water, when it was shown that the act of freezing may be carried to such an extent as to produce in the remaining water, a precipitation of the salts in solution, but ice frozen upon very superficial water was found very liable to have the impurities frozen in it which adhered to the under sides of the ice, and which became embedded in it by subsequent freezing, while water which has been largely deprived of air by boiling or exposure, upon being frozen, if perfectly crystalline, will produce absolutely pure water. Several patents have been taken out with a view to freezing sea water so as to furnish a supply of fresh water on board ship, but such processes will not compete, from an economical point of view, with the process of distillation.

GEOLOGICAL.

The geological formations which furnish water of a quality suitable to be softened are those of the dolomitic or magnesian limestone, which gives great hardness to water, for while salts of lime render water hard and troublesome in washing, those of magnesia cause the water to curdle and render it considerably more disagreeable for washing and ablution. The mountain limestone, which is ordinarily of an impermeable nature, does not yield water of such a hard quality as those of the magnesian lime-The waters of the oolite and stone. chalk are chiefly hard from what has been termed temporary hardness, that is due to the presence of bicarbonates of lime and magnesia in the water, which may be got rid of by boiling, or by the lime uneasy mind.

process. The waters of the new red sandstone and Permian beds vary considerably in hardness; many of them have a considerable permanent degree of hardness, but there are none of them which may not be softened to a great extent by the adoption of the lime process, while this process, in combination with the other alkali earths, such as soda, when the water is not intended to be used for dietetic and washing purposes, will still further reduce the hardness of these waters. The surface wells of the country, usually sunk in drift covering various geological formations, furnish water of various degrees of hardness. Scarcely any such wells yield a soft water, and in most instances, when these wells are sunk in populous places, in addition to their natural hardness, the waters are highly polluted, and such waters ought never to be used for dietetic purposes, unless they are first boiled.

RECENT Writer in the North China Herald discusses the part played by mercury in the alchemy and materia medica of the Chinese. Cinnabar was known to them in the seventh century before the Christian era, and its occurrence on the surface of the carth was said to indicate gold beneath. Their views on the transformation of metals into ores and ores into metals by heat and other means took the form of a chemical doctrine about a century before Christ, and there is now no reasonable doubt that the Arabian Geber and others (as stated by Dr. Gladstone in his inaugural address to the Chemical Society) derived their ideas on the transmutation of metals into gold and the belief in immunity from death by the use of the philosopher's stone from Among all the metals with which the China. alchemist worked, mercury was pre-eminent, and this is stated to be really the philosopher's stone, of which Geber, Kalid, and others spoke in the times of the early Caliphs. In China it was employed excessively as a medicine. On nights when dew was falling, a sufficient amount was collected to mix with the powder of cinnabar, and this was taken habitually, till it led to serious disturbance of the bodily functions. the ninth century an Emperor, and in the tenth a Prime Minister, died from overdoses of mercury. Chinese medical books say it takes two hundred years to produce cinnabar; in three hundred years it becomes lead; in two hundred years more it becomes silver, and then by obtaining a transforming substance called "vapor of harmony" it becomes gold. This doctrine of the transformation of mercury into other metals is 2000 years old in China Chinese hold that it not only prolongs life, but expels bad vapors, poison, and the gloom of an

MAXIMUM STRAINS IN JOINTED BOW GIRDERS.

BY EMMERICH A. WERNER, C. E.

Contributed to Van Nostrand's Engineering Magazine.

EXTERNAL FORCES IN BOW GIRDLES WITH JOINTS.

For the correct calculation of the strains in any girder, it is necessary to know the external forces acting upon it, and the greatest values they can assume.

To show how to find these external forces and their greatest values in bow girders with joints is the object of this treatise.

The external forces consist of the loads (primary forces) and the reactions of the abutments (secondary forces).

If only vertical reactions act upon the girder, it is called a beam, if vertical and horizontal reactions are acting, it is called a bow girder.

As there are only three equations expressing the equilibrium of the forces of a rigid system in the plane, it is only possible in the case of a beam on two supports to find the reactions of the abutments directly.—In all other cases the necessary equations for expressing the reactions of the abutments must be found by other means.-

The simplest way is the use of joints.— The joint presents no difficulty as to the construction, and gives on the other side, perfect security for correct acting.—The moments necessarily become zero in the joints

ABC represent that line of a bow girder, in which the horizontal reaction of the abutments, or the thrust of the bow is acting. I will call it the line of thrust.

The bow has joints on the abutments and in the crown. AB are the abutment $Hf = Q_1 \frac{l}{2} - G_3 \left(g_3 - \frac{l}{2}\right)$ (3) joints, C the crown joint.

Let the line ABC be referred to rectangular co-ordinates, with the origin in A.

QQH = be the vertical and horizontal reactions of the abutments.

l = span of girder.

f = ordinate of the crown joint, at the same time greatest ordinate of the bow.

 $G_1G_2G_3 = \text{sum of all the loads from}$ x=0 to x=x; from x=x to $x=\frac{t}{2}$ and from $\frac{l}{2}$ to l.

 $g_1g_2g_3$ = abscissae at the points of application of G, G, G,

 $M_x = \text{sum of the moments of all the}$ forces in the point x.

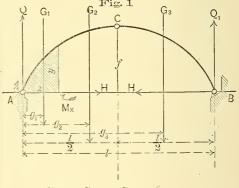
 V_x = the vertical reaction of the abutment, less G₁.

 $R_x = \text{sum of the shearing forces } nor$ mal to the line of thrust in the point x.

 $S_x = \text{sum of the } vertical \text{ shearing forces}$ in the point x.

 $\mu_x = \text{angle of the tangent of the line}$ of thrust in the point x, with the x

 μ_f =angle of BC or AC with the x axis.



$$Q_{1} = \frac{G_{1}g_{1} + G_{2}g_{2} + G_{3}g_{3}}{l} \quad . \quad . \quad . \quad (1)$$

$$Q = G_1 + G_2 + G_3 - Q_1$$

$$= G_1(l - g_1) + G_2(l - g_2) + G_3(l - g_3)$$
(2)

$$\mathbf{H} f = \mathbf{Q}_{1} \frac{l}{2} - \mathbf{G}_{3} \left(g_{3} - \frac{l}{2} \right) \quad . \quad . \quad . \quad . \quad (3)$$

$$H = \frac{G_{1}g_{1} + G_{2}g_{2} + G_{3} (l - g_{3})}{2f} . . . (4)$$

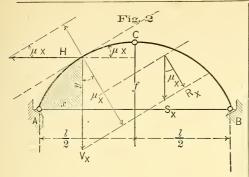
$$M_x = Qx - G_1(x - g_1) - Hy$$
 . . . (5)

$$\mathbf{M}_{x} = \mathbf{G}_{1}g_{1}\left\{1 - \frac{2fx + ly}{2fl}\right\} +$$

$$+ G_{2}\left\{ c - g_{2} \frac{2fx + ly}{2fl} \right\} + G_{3}(l - g_{3}) \left\{ \frac{2fx - ly}{2fl} \right\} (6)$$

$$V_x = Q - G_1$$

$$R_x = \frac{dM}{ds} = V_x \cos \mu_x - H \sin \mu_x \quad . \quad (7)$$



$$S_{x} = \frac{R_{x}}{\cos \cdot \mu_{x}} = \frac{dM}{dx} = V_{x} - H \text{ tang. } \mu_{x} \text{ (8)}$$

$$S = -G_{1}g_{1} \left(\frac{1}{l} + \frac{\tan g \cdot \mu_{x}}{2f} \right) + G_{2} \left\{ 1 - g_{2} \left(\frac{1}{l} + \frac{\tan g \cdot \mu_{x}}{2f} \right) \right\} + G_{3} \left(l - g_{3} \right) \left(\frac{1}{l} - \frac{\tan g \cdot \mu_{x}}{2f} \right) . (9)$$

$$S_{x} = o = \frac{2f}{l} \cdot \frac{G_{3}(l - g_{3}) + G_{2}(l - g_{2}) - G_{1}g_{1}}{G_{1}g_{1} + G_{2}g_{2} + G_{3}(l - g_{3})} - \frac{1}{l} \cdot \frac{1}{l} \left[\frac{1}{l} - \frac{1}{l} + \frac{1}{l$$

No restriction is made as to the distribution of the loads over the girder. The loads can be distributed in any way over the structure.

According to the *two* distinct kinds of loading, the disquisitions must also be divided into *two* distinct parts:

- (1) for loads at rest.
- (2) for moving loads.

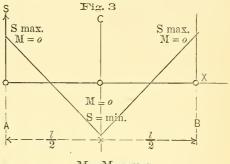
LOADS AT REST.

QQ,H.=REACTIONS OF THE ABUTMENTS. They are constant. The absolute value of H is *increasing* with *decreasing* f or height of the bow.

S=Shearing Forces.

 $S_x = \frac{dM}{dx}$, thus the value of S is a max. or min. in the points M = o and it is zero in the points corresponding to the maximum or minimum of M. In equation 9 the first member is always negative, hence S is a maximum in x = o and x = l and a minimum in $x = \frac{l}{2}$, M being necessarily zero in these points in consequence of the joints. S is zero in the points corresponding to $\frac{dM}{dx} = o$.

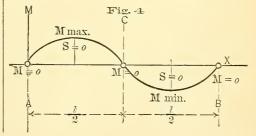
In using x as abscissa and S_x as ordinate, the law governing the values of S can be graphically represented by a plane curve—the curve of the shearing forces. The form of that curve depends upon the form of the line of thrust and the way of loading the girder. If the line of thrust is a common parabola and the loads are equally distributed over the girder, the curve of the shearing forces are two straight lines as represented in Fig. 3.



M = Moments.

The moments are zero in x=0 $x=\frac{t}{2}$ and x=t in consequence of the joints. In the points corresponding to $\frac{d\mathbf{M}}{ax}=0$ the values of \mathbf{M} are maximum or minimum. The values of \mathbf{M} increase or decrease as long as $\mathbf{S}_x = \frac{d\mathbf{M}}{dx}$ is positive or negative. In x=0 S is a maximum or positive, hence the values of the moments reach always a maximum between x=0 and $x=\frac{t}{2}$ and a minimum between $x=\frac{t}{2}$ and x=t.

If we use x as abscissa and $M_x = y$ as ordinate, the law governing the values of M will be represented by a plane curve—the curve of the moments.—The form of the curve of the moments also depends upon the form of the line of thrust and



the mode of loading. If the line of thrust is a common parabola and the loads are equally distributed over the girder, Fig. 4 represents the curve of the moments.

MOVING LOADS.

The value of the external forces now depends upon x as well as upon the positions of the loads on the girder. But in first taking x = constant and only altering the positions of the loads, we obtain the variations of the forces in a point of the girder and especially the positions of the loads corresponding to the maximum and minimum values, which the forces can assume. Considering then the moving of the loads over the girder, as a series of loads at rest, it will finally be easy to apply the above derived laws and especially to define the course of the maximum and minimum values.

QQ,H=REACTIONS OF THE ABUTMENTS.

Eqs. 1, 2, and 4 show that they are independent of x and vary only with the positions of the loads. All the members of these equations are positive and increase with G. Hence the values of QQ, H increase as the loads are covering the girder and reach their maximum with full loaded truss. The absolute value of H moreover increases with decreasing f or height of the bow.

M=Moments.

In equation 6-x, y being constant the first member is always positive, as can be easily verified in writing its coefficient:

$$\left(1 - \frac{2fx + ly}{2fl}\right) = \frac{l\left(f - y\right) + f\left(l - 2x\right)}{2fl}$$

The third member:

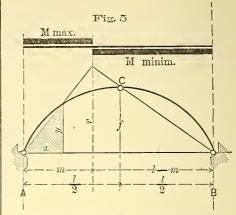
$$\mathbf{G}_{\mathrm{s}}(l-g_{\mathrm{s}})\left(\frac{2fx-ly}{2fl}\right) = \mathbf{G}_{\mathrm{s}}(l-g_{\mathrm{s}})\frac{x}{2}\left\{\frac{f}{l} - \frac{y}{x}\right\}$$

is always negative, $\frac{7}{1}$ being the tangent

of the angle of the chord AC or BC and the x axis; $\frac{y}{x}$ the tangent of the angle of Ay and the x axis.

The second member only can change its sign, while the loads are running over when the x axis is covered from x=0 to

the girder. The absolute value of M thus depends from the value of this second member, increasing or decreasing as long as it is positive or negative.



Hence M is a maximum or minimum,

$$x - g_2 \frac{2fx + ly}{2fl} = 0 \text{ or}$$

$$g_2 = \frac{2flx}{2fx + ly} = m \quad . \quad . \quad (11)$$

m can easily be graphically constructed. It is the abscissa of the intersection of the chords BC and Ay, Fig. 5. demonstration follows directly from the figure.

Equation 11 can be put in a more convenient form for use (see Fig. 5.) It is:

$$\frac{y}{x} = \frac{f}{\frac{l}{2}} \left(\frac{l}{m} - 1 \right) \quad . \quad . \quad (12)$$

or in calling $\frac{y}{x}$ = tang. y

$$m=l.\frac{\tan g. \mu_f}{\tan g. y + \tan g. \mu_f}$$
 . (13)

For $g_s = m$ the second member of equation (6) becomes zero. This is only possible when G_z itself is zero. Thus $g_z=m$ represents the limit of G, or that part of the x axis, which must be covered with the rolling load, to make the value of ${f M}$ a maximum or minimum.

Values of g_s less than m make the second member positive,—values greater than m make the second member nega-

Hence the value of M is a maximum

x=m, with rolling load, a minimum, when the x axis is covered from x=m to x=l with moving load, as represented in

Fig. 5.

This rule discloses a very remarkable property of the bow girder. It shows that the maximum or minimum of M in any point of the girder depends only upon the form of the line of thrust and is independent of the way the loads are

distributed over the girder.

In reversing the above given method, it is easy to find for any load at rest, that point of the girder, in which M is a maximum or minimum. It is sufficient to draw the chord BC and from the intersection with r—the ordinate at the end of the load—a line to A. The intersection of the latter line with the line of thrust is the point x,y in which M is a maximum or minimum according as the load covers the half-bow containing x or

If we now suppose for every point in the girder the positions of the rolling load, corresponding to the maximum and minimum of M, constructed in the above way, we shall have a series of loads at rest on which the rules for the latter can be

applied.

Thus the maximum or minimum value of M themselves must be zero in x=o; $x = \frac{1}{2}$ and x = l. They will increase or decrease, with increasing x, as long as $\frac{d \mathbf{M}}{dx} = \mathbf{S}_x$ is positive or negative. Eq. (9):

$$\begin{split} \mathbf{S}_{x} = & -\mathbf{G}_{1} g_{1} \left(\frac{1}{l} + \frac{\tan g. \ \mu_{x}}{2f} \right) + \\ & + \mathbf{G}_{2} \left(1 - g_{2} \frac{\tan g. \ \mu_{x}}{2f} \right) + \\ & + \mathbf{G}_{3} (l - g_{3}) \left(\frac{1}{l} - \frac{\tan g. \ \mu_{x}}{2f} \right) \end{split}$$

changes its sign, when

$$\frac{1}{l} - \frac{\tan g. \ \mu_x}{2f} = o$$

or in the point x, y corresponding to

tang.
$$\mu_x = \frac{f}{2} = \text{tang. } \mu_f \quad . \quad . \quad . \quad (14)$$

The point x, y, in which the maximum and minimum of the moments become an thus the point of contact of a tangent to ways positive.

the line of thrust parallel with the chord A C or B C.

In applying at that point the construction for maximum and minimum of M, it is easy to find the positions of the rolling load corresponding to the absolute maximum and minimum values of M in the girder.

This position is also independent of the mode of loading and only depends upon the form of the line of thrust. This fact can be verified in another way:-The absolute maximum and minimum being

independent of
$$G_1G_2G_3$$
, tang. $\mu_x = \frac{\overline{I}}{2}$

must be a root of the equation S=0, whatever be G1G2G3. This is indeed the case, as it is easy to ascertain from equation (10)

$$o = \frac{f}{2} \cdot \frac{G_{s}(l - g_{s}) + G_{s}(l - g_{s}) - G_{1}g_{1}}{G_{1}g_{1} + G_{2}g_{2} + G_{3}(l - g_{s})} -$$

$$- tang. \ \mu_{x}$$

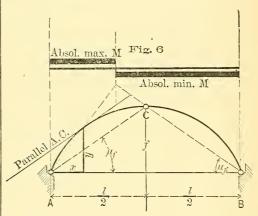


Fig. 6 shows the graphical construction of the point corresponding to the absolute maximal and minimal values of M.

S=Shearing Forces.

In equation (9) -x,y being constant.—

$$S_{x} = -G_{1}g_{1}\left(\frac{1}{l} + \frac{\tan g_{1} \mu_{x}}{2f}\right) + G_{2}\left\{1 - g_{2}\left(\frac{1}{l} + \frac{\tan g_{1} \mu_{x}}{2f}\right)\right\} + G_{3}(l - g_{3})\left(\frac{1}{l} - \frac{\tan g_{1} \mu_{x}}{2f}\right)$$
(9)

absolute maximum and minimum, is the coefficient of the first number is al-

The coefficient of the third member, or

$$\left(\frac{1}{l} - \frac{\tan g. \ \mu_x}{2f}\right) = \frac{1}{2fl} \left\{ \frac{f}{l} - \tan g. \ \mu_x \right\}$$

is positive or negative according as

tang.
$$\mu_x \lesssim \frac{f}{l}$$

Hence if

tang.
$$\mu_x > \frac{f}{l}$$

or for points between x=o and the point corresponding to the absolute maximum of M, that is

o < x < x corresponding abs. max. M.

The first and third member of equation (9) is negative, and if

tang.
$$\mu_x < \frac{f}{l}$$

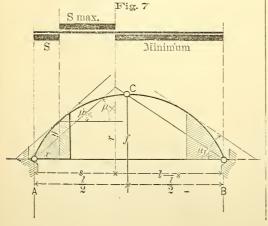
or for points between the point corresponding to the absolute maximum of M and the crown joint, that is

x corresponding abs. max. $M < x < \frac{l}{2}$ the first member is negative and the third

The second member changes its sign

$$g_2 = \frac{2fl}{2f + l \tan g, \ \mu_x} = s$$
 . (15)

s can be graphically constructed. It is the abscissa of the intersection of the



chord BC and a line from A parallel with the tangent in point x,y.

the tangent in point x,y.

The demonstration follows directly

from the figure.

A more convenient form of s for use is the following:— (see Fig. 7.)

tang.
$$\mu_x = \frac{f}{\frac{1}{2}} (\frac{l}{s} - 1)$$
 . (16)

$$s = l \cdot \frac{\text{tang. } \mu_f}{\text{tang. } \mu_x + \text{tang. } \mu_f} \quad . \quad . \quad (17)$$

s represents for reasons shown already by the moments, the limit of G_1 , or that part of the x axis, which must be covered with moving load to make S a maximum or a minimum.

Values of g_s less than s makes the second member of equation (9) positive, values greater than s negative. Hence, when

I tang.
$$\mu_x > \frac{f}{2}$$
 or,

o < x < x corresponding abs. max. M.

the first and third member of equation (9) being negative:

S is a maximum, when the parts of the girder corresponding to G_1 and G_3 are empty, or when the girder is covered with load from x=x to x=s, and

S is a minimum, when the girder is covered with loads from x=o to x=x and at the same time from x=s to x=l.

II tang.
$$\mu_x < \frac{f}{2}$$
 or,

x corresponding abs. max. $x < x < \frac{l}{2}$

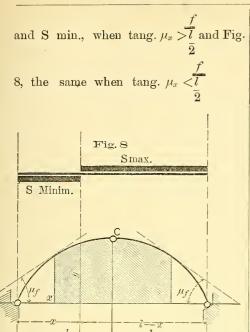
For tang.
$$\mu_x = \frac{f}{2}$$
, s becomes $=\frac{l}{2}$ and

the second member of equation (9) is positive, leaving only the first member negative; thus:—

S is a minimum, when the parts of the girder corresponding to G_2 and G_3 are covered with load, or when the girder is covered from x=x to x=l, with rolling load.

S is a minimum, when the girder is loaded from x=o to x=x.

Fig. 7 shows the graphical construction of the positions of the loads for S max.



Generally the loads will be concentrated in certain points of the girder—the panel points—and in constructing the positions of the loads corresponding to the maximum and minimum of M and S the beginning and end of m and s will fall either between two panel points or coincide with a panel point itself, and the question arises, how far the loads must in each case cover the girder to produce the maximum or minimum values.

If the end of m or s falls between tvo panel points, the answer presents no difficulty. i and (i+1) be the two points, then evidently m or s will be covered completely with moving load, if the girder is covered from m=o or s=o to the point i (inclusive) and (l-m) or (l-s) will be completely loaded, when the girder is covered from (i+1) including this point to l and it will be easy in each case to find the positions of the moving loads corresponding to a maximum or minimum.

Not so, if the beginning or end of m or s coincides with a panel point itself. It is then impossible a priori to decide whether the point must be covered with load or not to produce M or S maximum or minimum, but a decision can be reached in the following way:

I begin with s the value governing the maximum and minimum of S the shearing forces, and we must bear well in mind, that S is not acting in a point, but as well as tang. μ_x in the whole panel.

I.

THE BEGINNING OF S COINCIDES WITH A PANEL POINT.

Fig. 9 represents the positions of the rolling load with regard to the panel x.

P=be the sum of all the moving loads acting upon the girder.

a = coefficient expressing the ratio of P to Q_n .

b=that part of P forming with $Q_1 \frac{l}{2f}$ the thrust H.

 $\alpha, \beta, \gamma, \triangle$ panel lengths.

 $p, p_1 = \text{loads in different panel points.}$

Note. P, a, b are of different value for each position of the loads, but as no mistake is possible, no especial letters have been used.

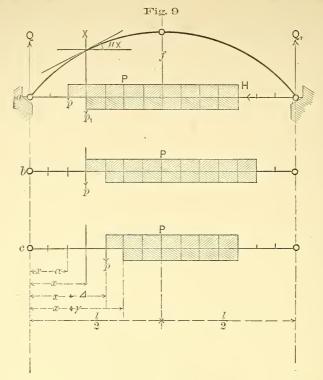
The other letters have the previous significations.

Fig. 9 a=The loads cover the girder from the point (x-a) to any point towards B and again from the point x to the same point towards B. It is:

$$\begin{vmatrix} (x-a) & (x) \\ Q_1^{x-a} = aP. \\ Q^{x-a} = P - Q_1^{x-a} & Q_1^x = aP - \left(\frac{x-a}{l}\right)p \\ H^{x-a} = Q_1^{x-a} \frac{l}{2f} - b & Q^x = P - p - Q_1^x \\ H^x = Q_1^x \frac{l}{2f} - b & H^x = Q_1^x \frac{l}{2f} - b \end{vmatrix}$$

$$S_x^{x-a} = P - Q_1^{x-a} - p - p_1 - Q_1^x - a\left(\frac{l}{2f} tang. \ \mu_x\right) - b \ tang. \ \mu_x = P - \left\{Q_1^{x-a}\left(1 + \frac{l}{2f} tang. \ \mu_x\right) + b \ tang. \ \mu_x + p + p_1\right\}$$

$$S_x^x = P - Q_1^x - p - p_1 - Q_1^x \left(\frac{l}{2f} tang. \ \mu_x\right) - b \ tang. \ \mu_x = P - \left\{Q_1^x \left(1 + \frac{l}{2f} tang. \ \mu_x\right) + b \ tang. \ \mu_x + p + p_1\right\}$$



HENCE:

$$S_x^{x-a} < S_x^x$$
 when $Q_1^{x-a} > Q_1^x$ or $\frac{x-a}{l} > o$

Fig. 9 b=The loads cover the girder from the point x and again from $(x + \triangle)$. It is:

$$S_x^x < S_x^{x+\Delta}$$
 when:
 $Q_1^x > Q_1^{x+\Delta}$ or $\frac{x}{L} > 0$

Fig. 9 c—The loads cover the girder from the point $(x + \triangle)$ and again from $(x + \gamma)$. It is:

$$\mathbf{S}_{x}^{x} + \Delta < \mathbf{S}_{x}^{x} + \gamma \text{ when:}$$

$$\tan g. \ \mu_{x} > \frac{f}{2} \left(\frac{l}{x + \Delta} - 1 \right) \text{or} \quad . \quad (18)$$

$$\frac{\tan g. \ \mu_{x}}{l - (x + \Delta)} > \frac{f}{l} \quad . \quad . \quad (19)$$

Recapitulating we find, that always

$$S_x^{x-a} < S_x^x < S_x^{x+\Delta} > S_x^{x+\gamma} ... (20)$$

The first two conditions result directly from the above equations. The last one:

$$S_x^{x+\Delta} > S_x^{x+\gamma}$$

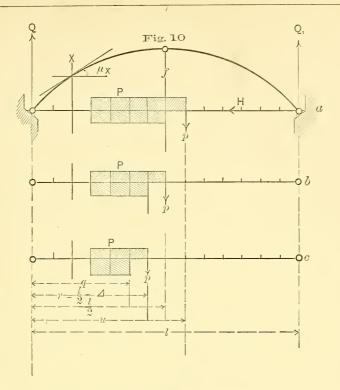
is demonstrated as follows:

Equation 18 shows that tang. μ_x must

be
$$> \frac{\overline{l}}{2}$$
 to have $S^{x+\Delta} < S_x^{x+\gamma}$. This

is the case only in panels between x=o and the x corresponding to the abs. maximum or minimum of—the moments. Hence it is only necessary to take panels in consideration from x=o to x=abs. maximum or minimum of M. But it is evident, that in this part of the line of thrust, tang. μ_x is a max. when x is as small as possible. Thus considering the first panel of the girder we shall have tang. $\mu_x=$ max. The value of tang. $\mu_x=$ in the first panel is:

tang
$$\mu_x = \frac{y}{x + \Delta}$$



Using this value in equation 19, we find

$$\frac{y}{l-(x+\Delta)} > \frac{f}{2}$$

but as y is always < f and $\lfloor l - (x + \triangle) \rfloor > \frac{l}{2}$ the above inequality can never be fulfilled and we find equation (20). The equation (20) shows that for S_x max. in panel x, the loads always begin in $(x + \Delta)$, while for S min. in panel x, the loads always cover the point x. $H^u = Q_1^u \frac{l}{2f} - p \binom{2u - l}{2f} \qquad Q_2^{\frac{l}{2}} = P - p \binom{2u - l}{2f} \qquad Q_2^{\frac{l}{2}} = Q_2^{\frac{l}{2}} \qquad Q_2^{\frac{l}{2}} \qquad Q_2^{\frac{l}{2}} = Q_2^{\frac{l}{2}} \qquad Q_2^{\frac{l}{2}} \qquad Q_2^{\frac{l}{2}} = Q_2^{\frac{l}{2}} \qquad Q_2^{\frac$

II.

THE END OF S COINCIDES WITH A PANEL POINT.

Fig. 10 represents the positions of the loads with regard to the panel x and the crown joint, in the vicinity of which the end of s falls always.

Fig. 10a=The girder is covered from $(x + \triangle)$ to u, and again to $\frac{l}{2}$ with moving loads. It is

$$u \qquad \frac{l}{2}$$

$$\frac{Q_{1}^{u} = aP}{Q^{u} = P - Q_{1}^{u}}$$

$$H^{u} = Q_{1}^{u} \frac{l}{2f} - p\binom{2u - l}{2f} \begin{vmatrix} Q_{1}^{\frac{l}{2}} = aP - \frac{u}{l}p \\ Q_{2}^{\frac{l}{2}} = P - Q_{1}^{\frac{l}{2}} \end{vmatrix}$$

$$= \frac{l}{2} = Q_{1}^{\frac{l}{2}} \frac{2f}{l}$$
and
$$S_{x}^{u} = P - \left\{ Q_{1}^{u} \left(1 + \frac{l}{2f} tang. \ \mu_{x} \right) - -p\left(\frac{2u - l}{2f} tang. \ \mu_{x} \right) \right\}$$

$$S_{x}^{\frac{l}{2}} = P - \left\{ Q_{1}^{\frac{l}{2}} \left(1 + \frac{l}{2f} tang. \ \mu_{x} \right) + p \right\}$$
hence,
$$S_{x}^{u} < S_{x}^{\frac{l}{2}} \text{ when}$$

$$tang. \ \mu_{x} > \frac{f}{2} \quad . \quad . \quad (21)$$

Fig. 10 b=The loads cover the girder

from $(x + \triangle)$ to $\frac{l}{2}$ and again to r. It is $\operatorname{S}_{x}^{\frac{l}{2}} < \operatorname{S}_{x}^{r} \text{ when}$

tang.
$$\mu_x > \frac{f}{2}$$
 . . . (22)

Fig. 10 c=The loads cover the girder from $(x + \triangle)$ to r and again to t. It is—

$$S_{x}^{r} < S_{x}^{t} \text{ when}$$
tang. $\mu_{x} > \frac{f}{2} \left(\frac{l}{r} - 1 \right)$. . . (23)

If tang. μ_x is exactly $\frac{f}{l}$, equations (21)

and (22) give—

$$S_x^l = S_x^{l-1} = \dots = S_{\frac{l}{2}} = S_x^{r} = (\frac{l}{2} - \Delta)$$

or S maximum is reached in the panel corresponding to tang. $\mu_x = \frac{f}{l}$, by loading

the girder from $(x + \Delta)$ to any point be-

tween $r = \left(\frac{l}{2} - \Delta\right)$ and l. But, though

the maximum of S is reached by any one of the above positions, the strains induced in the members of the girder are not the same for each of the mentioned positions, as will be shown when we shall consider the strains in the members, and with regard to the maximum of the strains in the members of the girder, S is a maximum, when the girder is loaded from

$$(x + \triangle)$$
 to r or to $(\frac{l}{2} - \triangle)$

Equation (23) shows further that, if

tang.
$$\mu_x$$
 is exactly $\frac{f}{2} \left(\frac{l}{r} - 1 \right)$

$$S_x^r = S_x^{(r-\triangle)=t}$$

or that the girder may as well be loaded, say, to r as to $(r-\Delta)$ to obtain S maximum in the panel corresponding to

tang.
$$\mu_x = \frac{f}{2} \left(\frac{l}{r} - 1 \right)$$

Accordingly, S minimum would begin either with r or with $(r+\Delta)$. But only the last position of the loads will produce S minimum. Hence, though S maximum may be reached, in the above special case, in the mentioned two ways, S is a maximum, with regard to the minimum, when the girder is covered to r, and not to $(r-\Delta)$ with load.

Recapitulating, and assuming S to be a maximum, we find that the end of s never

extends beyond
$$\left(\frac{l}{2}-\Delta\right)$$
. But s can be-

come less than
$$\left(\frac{l}{2}-\varDelta\right)$$
, according to the

form of the line of thrust. The end of s will extend only to the following points, or the rolling loads will cover the girder only to the point—

$$t$$
 (inclusive) when tang. $\mu_x > \frac{f}{2} \left(\frac{l}{r} - 1 \right)$

$$\gamma$$
 (inclusive) when tang. $\mu_x > \frac{f}{2} \left(\frac{l}{t} - 1 \right)$

and so-forth.

If the panels are of equal length and 2n is their number—the loads may be different in each one—then the loads cover the girder to the point, including this point:—

$$\left(\frac{l}{2}-2\right)$$
 when: tang. $\mu_x > \frac{f}{2}\left(\frac{n+1}{n-1}\right)$. (24)

$$\left(\frac{l}{2}-3\right)$$
 when tang. $\mu_x > \frac{f}{2}\left(\frac{n+2}{n-2}\right)$. (25)

and so-forth.

For S minimum, (l-s) always begins with the point following the end of s.

The equations (21) to (25) are simply applications of the general equation (16).

The shearing forces in the first panel and the panel containing the crown joints, are:—

$$S_{I} = \frac{+M^{I}}{2}$$
 and

$$\mathbf{S}_{\substack{l \\ \overline{2}}} = + \frac{\mathbf{M}}{2} \left(\frac{l}{2} - \Delta \right)$$

and their maximum and minimum depends upon the positions of the loads corresponding to $M_{\rm I}$ and M $\left(\frac{l}{2}-\varDelta\right)$

maximum and minimum.

We now turn to m, the length of the x axis governing the maximum and minimum of the moments.

We shall consider m corresponding to M maximum.

The beginning of m always lies in x=o and nothing special is to be remembered.

The End of m Coincides with a Panel Point.

Equation (13):—

$$m = l \cdot \frac{\text{tang, } \mu_f}{\text{tang. } y + \text{tang. } \mu_f}$$

is exactly the same as equation 17.

$$s=l. \frac{\tan g. \mu_f}{\tan g. \mu_x + \tan g. \mu_f}$$

when we substitute tang. y for tang. μ_x and the deductions from equation (17), will also hold good for equation (13).

Hence, if the end of m coincides with a panel point, say r, it will not alter the absolute value of M maximum, when the girder is covered either to r or to $(r-\Delta)$, but, as by s, with regard to the minimum, M is a maximum, when the girder is loaded to r and not to $(r-\Delta)$. Concerning the absolute maximum or minimum of M, it is necessary to bear in mind, that the criterion is bound to tang. μ_x , and that tang. μ_x means not a point, but a whole panel.

In case of M minimum, (l-m) always begins with the next point following the

end of m.

Before I now proceed to show by an example how plain the application of these rules is in reality, I will recapitulate them in few words.

MOMENTS.

Draw in any point x,y, Ay and BC—see Fig. 5.—The intersection of these lines lies in the panel point m or between Vol. XXXI.—No. 4—23

m and $m + \Delta$, and it will be in the point x, y:

M a maximum, when from o to inclusive point m.

M a minimum, when from inclusive point $(m + \Delta)$ to l the girder is covered with loads.

Draw a tangent to the line of thrust parallel with the chord AC or BC. The point of contact gives the point of abs. maximum or minimum of M—see Fig. 6.

SHEARING FORCES

I. Panels in which tang. $\mu_x > \frac{f}{l}$, or

 $o < x < x_s$ corresponding abs. max. M

Draw BC and from A a line parallel with tang. x, y—see Fig. 7.—The intersection of both lines lies in the panel point s or between s and $(s+\Delta)$ and it will be in the panel x.

S a maximum, when from inclusive point $(x + \Delta)$ to inclusive point s.

S a minimum, when from o to inclusive point x and at the same time from inclusive point $(s + \Delta)$ to l the girder is covered with loads.

II. Panels, in which tang. $\mu_x < \frac{f}{l \text{ or }}$

x correspond. abs. maximum $M < x < \frac{l}{2}$

Note.—The tang. μ_x must be smaller

than
$$\frac{f}{2}$$
—see Fig. 8.—

In the panel x, it will be:

S a maximum, when from inclusive point $(x + \Delta)$ to l.

S a minimum, when from o to inclusive point x the girder is covered with loads.

 S_{I} and $S_{\frac{1}{2}}$ have their maxima and min-

ima with $M_{\rm I}$ and $M_{\frac{l}{2}}-\Delta$) max. or min.

If calculation is preferred, calculate:

1. tang. μ_x in the panels I to $\frac{\ell}{2}$

The nearest value of tang. μ_x to $\frac{\vec{l}}{2}$

gives the panel of the absolute max. or min. of M.

2. Calculate *m* from equation 13 for each panel point and proceed as shown previously.

3. Calculate s from equation 17 and per panel.

proceed as shown above.

I use both methods together, generally employing the graphical method and the calculation only, where the end of m or s falls so near a panel point, that a sharper definition is wanted.

It is hardly necessary to say, that to the effects of the rolling loads must be added the effect of any load at rest.

EXAMPLE.

Figure 11 represents the line of

thrust of a girder of 150' span. It has 10 panels of 15' length. f is 30'. The line of thrust is a common parabola. The own weight is assumed to 18,000 lbs. per panel, the rolling load to 45,000 lbs. per panel.

 $QQ_{1}H.$

It is only necessary to calculate the reactions of the own weight and for the moving loads, the values corresponding to the successive positions from x=o to $x=\frac{l}{2}$ and for full loaded girder. All other values are found by addition or subtraction as shown, by M minima.

Own weight= $Q^{E} = Q_{_{1}}^{E} = 81000 \text{ lbs.}$ Own weight= $H^{E} = 112500 \text{ lbs.}$

Only Moving Loads. -Q, NQNHN.

Loaded from point o to point—	Q_1 .	Δ1.	Δ 11.	$Q+Q_1$.	Q.	H.	
0 to 1 0 to 2 0 to 3 0 to 4 0 to 5	$\begin{array}{c} 4500 = \frac{1}{10} \\ 13500 = \frac{3}{10} \\ 27000 = \frac{6}{10} \\ 45000 = \frac{10}{10} \\ 67500 = \frac{15}{10} \end{array}$	9000 13500 18000 22500	4500 4500 4500	45000 90000 135000 180000 225000	40500 76500 108000 135000 157500	11250 33750 67500 112500 16875	$f = Q_1 \frac{l}{2}$ H=2.5 Q ₁ .

Full load= $Q^{N} = Q_{1}^{N} = 202500$ lbs. Full load= $H^{N} = 281250$ lbs.

In these and the following calculations much time and labor can be saved, in using instead of the panel length, the ratio of this length to the span—here $\frac{1}{10}$.

It is then
$$Q_1^{(o-1)}=1\times\frac{p}{10}$$
, $Q_1^{(o-2)}=(1+2)$
=3× $\frac{p}{10}$, . . . and the calculation of

 Q_1 for the different positions of the moving loads is reduced to a multiplication of $Q_1^{(o-1)}$ with the sum of the panel indices of the loaded panels, as shown above, or

The correctness of the calculation can moreover be easily verified, the values of Q_1 forming a higher arithmetical seria, which is shown above.

For calculation of H use equation 3, for instance:

Full loaded
$$H^{N} = \frac{202500 \times 5 - 45000 \times 10}{2} = 281250$$
 lbs.

MOMENTS.

Use equation 5 for calculation—
—See Fig. 11b—
Draw BC and Ay in each panel point.

Maxima-

for M_1 and M_2 loaded from o to point 3 Q=189,000 lbs. H=180,000 lbs.

for M_3 and M_4 loaded from o to point 4 Q=216,000 lbs. H=225,000 lbs.

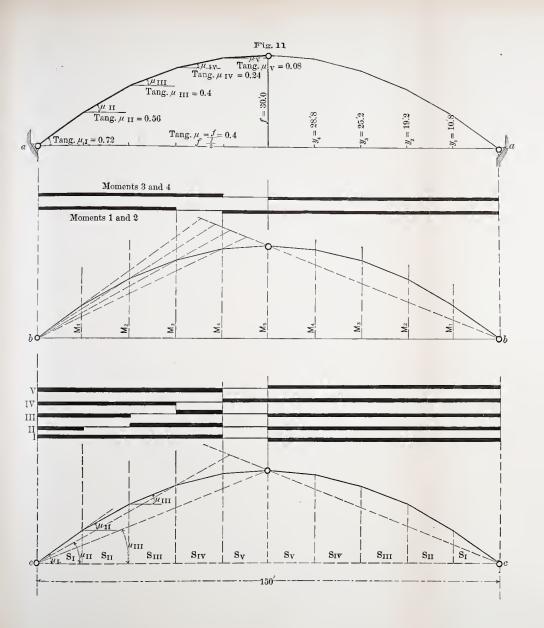
 $M_1 = +89100 \text{ f. lbs.}$

 $M_2 = + (189,000 \times 15) \times 2 - 63,000 \times 15 - \\ -180,000 \times 19'2 = +1,269,000 \text{ f. lbs.}$

 $M_s = +1,215,000 \text{ f. lbs.}$

 $M_4 = +810,000 \text{ f. lbs.}$







Minima.

for
$$M_s$$
 and M_4 loaded from 5 to 10, $Q=148,500$ lbs. $H=281,250$ lbs. $M_1=-891,000$ f. lbs. $M_2=-1,269,000$ f. lbs. $M_3=-1,215,000$ f. lbs. $M_4=-810,000$ f. lbs. Shearing Forces. $-(\text{see Fig. }11c.)-$

Use equation 8 for calculation—

Draw BC and the lines parallel to the corresponding tangent in each panel.

$$S = \frac{M_1 \text{ max.}}{4} = +59,700 \text{ lbs.}$$

Minimum.

$$S_i = -\frac{M_i}{4} = -59,400 \text{ lbs.}$$

 S_{ii} loaded 0-1 & 5-10=-37,800 lbs. S_{iii} loaded 0-2 & 5-10=-27,000 lbs. S_{iv} loaded 0-3=-43,200 lbs.

$$S_v$$
 loaded $0-4=\frac{M_4}{4}=-54,000$ lbs.

With the knowledge of the external forces, the calculation of the strains in members of the girder is subject to no difficulty, as I will show later.

CO-OPERATION BETWEEN NATIONAL AND STATE GOVERN-MENTS IN TOPOGRAPHICAL SURVEYS.

BY H. F. WALLING.

Read before the American Society of Civil Engineers at the Buffalo Meeting.

and other well-informed persons that other avenues of internal communication, good topographical surveys are among the abundance and efficiency of which the necessities of nations for the econom- afford to the political economist the most ical construction of public works and for reliable measures of the comparative other useful purposes, this knowledge prosperity of different countries or pordoes not appear to be shared by the peotions of the same country. The relation ple in general, or by their legislators. between this prosperity and the construc-Our widely extended and comparatively tion of railways and other public works new country, now fairly entered upon its becomes one of recurring action and resecond century of national existence, although in many respects quite as advanced as the older European nations, has, much to its disadvantage, allowed itself to be outstripped by them in this litely. With good topographical maps matter.

topographical surveys are put is their of the map, and much of the uncertainty

While it is known by civil engineers guidance in the location of railways and action, and the effects are accumulative. The public works cause an increase of prosperity which in turn calls for more public works, and so on almost indefinthe best location for a road or railway is Among the primary uses to which readily determined by a careful inspection

as well as the expense of preliminary surveys is avoided.

In Great Britain, for example, when a new railway is proposed, the best route is first sought by a careful examination of the "Ordnance Maps," upon which exhaustive comparisons of all possible routes can be made as to grades, curves, excavations, embankments, etc., and from the data thus obtained the preferable The "Parlialocation can be chosen. mentary map" has this selected line laid down upon sheets of the ordnance map, where it can be intelligently considered by a parliamentary committee before legal authority is granted for building the road.

This preliminary map does not usually differ essentially from the more exact map of final location, and the cost of building the road, after so careful a selection of the route, is likely to be as small as possible. Most of the railways of our own country, unfortunately, were constructed without such a valuable preliminary guide and the result has been marked by great waste. It has been estimated by a railway engineer, a friend of the writer, that had the State of Massachusetts been in possession of a good topographical map in 1836, some \$20,000,000 would probably have been saved in its public railway expenditures. While it is too late, as he says, to recall the \$20,000,000 of unremunerative investments, it is not too late by means of a good survey, to guide private and corporate capital in the economical development hereafter of the various public works which will be demanded by the growing commonwealth.

If a cause be sought for the failure in this country to carry out a measure of obviously wise economy, in which every country in Europe has led the way, with the approbation of all their intelligent citizens, it is to be found, partially at least, in the peculiarities of our form of government, limited to matters of national safety, commerce with foreign nations, management of public property and certain inter-state relations which are regulated under the appropriate departments of the government.

A strong sentiment has prevailed from the outset against any extension of the general government, and up to the present time no direct national legislation has

authorized a topographical survey of the country.

In the meantime State legislatures have been slow to see the need of costly surveys and they have been undertaken in but a very few of the States. In some of these, creditable work has been commenced, but in none has it been brought to completion. The State of Massachusetts took the lead in 1829-30 when resolves were passed by the General Court requiring each town in the commonwealth to forward to the Secretary's office an accurate map of its territory on a scale of 100 rods to an inch (nearly 1:20,000). In accordance with subsequent legislation a trigonometrical survey of great excellence was completed in and the town surveys, after a much needed revision and correction were fitted into the framework of the triangulation. The result was a very good map of the State, the best of its kind indeed that has been made of any of the United States up to the present time. It was drawn upon the scale of two-fifths of an inch to a mile (1:158,400) and engraved on copper. The geographical positions of the sea coast, rivers, streams, lakes, roads, railways, town boundaries, villages, etc., were given with commendable accuracy. The smallness of the scale, however, while permitting the use of the map in one connected sheet, which may conveniently hang on the wall, greatly limits the other uses to which it may be put.

Moreover, the map lacks an important feature, needed to bring it up to the standard of the best of the more modern European maps, and to make it available for engineering requirements, namely, the accurate expression of the vertical relations between the objects represented, in other words their heights above a standard level. Borden's survey determined the heights of most of his primary stations above the level of the sea, and these heights are marked upon the map. But the only other indication of difference of level is by an imperfect system of hachures, which, while attempting to indicate the direction and steepness of slopes, fails to show the differences of level, quantitatively or even qualitatively, except between adjacent areas. The inadequacy of the most perfect system of hachures to intelligently represent quan-

by consulting the best maps constructed Up to the present time, however, but litin that manner. Among these are some the alacrity has been displayed on the of the official maps, already mentioned, part of individual States in availing themof European countries, which are exceedingly beautiful as pictures, or sam- Special triangulations have only been ples of fine engraving, but fail entirely to made in New Hampshire, New Jersey, convey definite hypsometric information. Pennsylvania, Kentucky, Tennessee and Practical good sense however seems like- Wisconsin, by the Coast and Geodetic ly to prevail over that conservative ten- Survey. acity which opposes even the most obvious reforms and the elaborate hachure tion, an elaborate topographical survey systems of Lehman and others are falling of a narrow strip of land along and adinto disuse, especially upon maps of large | joining portions of the Atlantic coast has scale and corresponding minuteness of been made under the Coast Survey. The detail.

"contour lines," as they are called, if ac-scale of 1:10,000 or nearly that of the curately drawn, are much more effective later maps of the British Ordnance Surin showing, not only the great general vey, namely, six inches to a mile. Upon features, but the minute details of height these sheets contour lines are marked inequalities, and if delicately indicative with vertical intervals, usually of twenty lights and shadows accompany the confeet. The details of topography are tour lines, the general relief of the coun-otherwise shown with great minuteness. try may be made to appear at a glance, A series of sheets of this kind for the while the absolute heights can everywhere whole country would be of incalculable be ascertained by easy inspection. The value for engineering and other purposes. intervals of level between these contour lines must be determined in relation to portant feature which gives great value the scale of the map and the amount of to the Ordnance and some other European

elaboration intended.

State authorities, a topographical and geological map of lines of actual ownership is a work inone-fourth of an inch to a mile with one from the imperfection and conflicting hundred feet contours) some of the nature of the various kinds of evidence preliminary steps have been taken along depended upon. the coast regions of the country. The for a topographical map of the country, geological and topographical surveys, adjustment of betterments for public

In addition to the work of triangulaplane table method was employed, the Lines of equal surface elevation or field sheets being generally upon the

They would, however, still lack an immaps, namely, the delineation of prop-Although no complete surveys of the erty lines. The Coast Survey maps show scope indicated above have been made by fences and other lines of enclosure, but . . . (The United without regard to ownership. As all land States Geological Survey has completed surveyors know, the determination of the the State of Colorado upon a scale of volving peculiar difficulties, arising mainly

In Great Britain the Ordnance Survey-United States Coast and Geodetic Sur- ors are required to serve regular formal vey, which for many years has been car- notices upon the land owners or their ried on by men of unsurpassed attain- legal representatives, who are notified to ments in their special departments of be present at the time of the survey for science, has laid the geodetic foundation the purpose of pointing out their lines and presenting the confirmatory evidence so far as the work has been completed, in their possession. By this means an along the two great oceans, the Gulf of official character is given to these bound-Mexico, the lower Mississippi, the Hud- ary surveys which has the general subseson River and Lake Champlain, by a triangulation unsurpassed throughout the trons litigation which might otherwise world for precision. Moreover, the pre- arise. The addition of property lines, cedent has been established by Congress, with adequate descriptions, constituting and is not likely to be departed from, of what are called "cadastral maps," not making special appropriations for extend-only serves to strengthen and perfect ing this geodetic triangulation into States titles, but renders the maps useful for where the legislature will provide for the equitable assessment of taxes, the

improvements, etc. The use of cadastral country. The desirability of this is apmaps has already extended to Canada and to some of the larger American cities and towns.

Since, with its present organization and yearly appropriations, it would require many centuries to complete a survey of the entire country, in the style of the narrow strip above mentioned, even without the cadastral element, the work of the Coast and Geodetic Survey is at present limited to the completion of its series of admirable coast charts and the valuable scientific investigations connected therewith, and to the extension of the geodetic work across the continent from ocean to ocean. This grand triangulation, when completed, will afford an admirable basis for topographical maps made by such special organizations as the various needs of different sections may indicate.

The position of the Atlantic States gives them the advantage of the primary triangulation of the Coast Survey which already extends across the New England accrue from this undertaking even while States to the Hudson River and Lake Champlain, and along the Blue Ridge and adjacent mountains of the Appalachian chain in Maryland, Virginia, West like ours. Virginia, North Carolina, South Carolina, Georgia and Alabama. In addition to this general primary or geodetic triangulation the Coast Survey organization is well adapted to supply the secondary triangulation by which the geographical positions of many convenient points intermediate between the primary stations would be given for the convenience of the surveyors who would follow and work up the minute details of topography. Government co-operation to this extent with State surveys, topographical and geological, has already been established in the States of New Hampshire, Pennsylvania, and New Jersey, and will doubtless be called for in all the States successively as the advantages of topographical surveys become apparent to them.

In the meantime another government organization has undertaken the preparation of topographical maps and is prepared to co-operate with States in The United States Geo- remains in the aboriginal condition of this work. logical Survey, originally organized to nearly unbroken solitude. Portions of investigate the geological relations and this unsettled country are more or less resources of the national domain in the susceptible of cultivation, or possess minwestern territories, has been authorized eral or other industrial resources. These to extend its researches over the entire portions will eventually partake of the

parent when we consider that geological formations are independent of civil boundaries, and that their relations can be best ascertained by tracing them from State to State over the widest accessible areas.

The absence of good topographical maps presents at the outset a formidable difficulty in the way of geological investigation. Geology and topography are intimately related and, to a considerable extent, dependent upon each other. The officers of the Geological Survey are accordingly compelled to supply the deficiency by constructing maps for themselves as the work goes on. For this purpose a "Division of Geography" has been organized, with an accomplished and experienced chief, under whose direction skilled topographers are assigned to the sections where immediate geological work is intended.

The immediate benefits which will in progress are so apparent that, having been fairly inaugurated, it is not likely to be abandoned in a progressive country

Its magnitude, however, assumes almost overwhelming proportions and the conditions under which it must be exercised are such as to call into exercise, judgment, skill and executive ability of a very high order. While the results must be reliable and accurate, rapidity of execution and economy in expenditure are also indispensable.

The first consideration which presents itself is that different parts of the country will need to be surveyed with different degrees of elaboration on account of the great variations in existing conditions. The older and more fertile portions of the country are already occupied by a dense population, much of which is concentrated in and about numerous large cities, towns and villages. An intricate network of roads and railways affords easy inter-communication between all parts of this inhabited region. On the

other hand a large part of the country

country and its accompanying develop- Congress for the Geological Survey must ment of cities, towns, roads and railways. be divided between the geological and But there will always remain vast regions the topographical work, which are to go made up of wild mountain peaks, ridges, with steep rock-bestrewn slopes, precipiers keeping a little in advance of the tous cliffs, deep gorges, broad stretches geologists. The work of the "Division of bare rock cut by impassable cañons territory.

A high degree of precision in the rendering of minute details cannot be obtained in these wildernesses, except at a cost of labor greatly disproportionate to the uses which can be made of the maps. If the more general topographical features, only, are accurately shown, all useful purposes will be subserved, and the scale may be

elaborated with greater precision.

The scale adopted for maps which have been made under the U. S. Geological Survey, is one-fourth of an inch to a mile, and this will doubtless prove adequate for the record of such geological characteristics as can be ascertained for many years. In some of the mining districts, however, where the presence of rich metallic veins has caused a rapid settlement of the locality by eager searchers for wealth, the details of geological inforto require special maps on a large scale

for their proper display. co-operation between State authorities and the U.S. Geological Survey in the construction of topographical maps has an important bearing in determining the scales which may be adopted by the Geological Survey, for the maps of those sections of the country included under State jurisdictions. Such a co-operation, for example has been proposed for the State of Massachusetts and is now under consideration by its legislature. The Georepresentation of the geological formaand other indications may be accurately located by the geologist, both in their present official map of Massachusetts, horizontal and vertical relations. more numerous the recognizable points of the larger Ordnance maps of Great of reference, and the narrower the spaces Britain, six inches to a mile is, in linear between them, the greater will be the dimensions, as one to fifteen; in area, as degree of precision with which he will be 1 to 225. That is, it would take 225 able to record his researches, and the times as many sheets of the same size to

general increase in the population of the But the limited sum appropriated by on nearly simultaneously, the topographof Geography," though preceding it in and great tracts of arid and uninhabitable the order of time, is subsidiary to the regular geological work of the survey, and is likely to receive a smaller share of the entire appropriation.

> In the absence of co-operation by any State with the United States Geological Survey, in preparing the topographical map of that State, this limitation of means will, of course, appear in the final result.

In Massachusetts the scale of the exmuch smaller than when the details are isting State map is, as stated above, twofifths of an inch to a mile. The U.S. Geological Survey has already done some preliminary work there, with a view of constructing a map with contour lines, on a scale of half an inch to a mile. It is evident, however, that this scale, about one-half that of the first British Ordnance Survey, would, like that, prove inadequate to serve the engineering and other purposes for which maps are needed by States and municipalities. In 1824 while the work of the Ordnance Survey was in mation developed by the miners are found progress in England, it was found necessary by the government to make a general property valuation of all Ireland. The question whether there shall be For this purpose the survey of that island was made on the scale of six inches to a mile, or 1:10,560 and the boundaries of farms, etc., were all carefully surveyed and delineated in addition to the other details of topography. When the survey of Ireland was finished in 1840 the maps were found so useful for other uses that the same scale was adopted for a re-survey of the kingdom, and, though the work was from time to time obstructed by the lack of adequate parliamentary logical Survey needs as a basis for its appropriations, its real value has been so apparent that it has not been discontintions, a map upon which the outcrops ued, and it must now be near completion.

The difference between the scale of the The two-fifths of an inch to a mile, and that more valuable will the record become, show the whole of Massachusetts, upon the scale of the Ordnance map, as upon be adopted for the intervals between conbe undertaken at present, and for the mountainous regions. general map of the State, a publication scale of 1:50,000, or about one and a with the surveys of Europe, the following quarter inches to a mile is probably as concise account of some of them has been large as would be required for most of taken from an interesting paper in the the purposes for which it would be used, North American Review for July, 1875, including preliminary investigations for on "Geographical Surveys," by Professor railway locations, for water supply of J. D. Whitney, who has given careful atcities, etc. This scale has been recom-tention to this subject: mended by international scientific conand convenient for general uses. cover ten minutes of latitude and twenty tional sheets along the sea coast.

giving property lines, areas of lots, etc.

streams, fences, stone-walls, buildings,

1:50,000 proposed, twenty-five feet might sold in single sheets as wanted at very

Borden's map. The cost of adopting the tours over the more level portions of the Ordnance scale is evidently too great to State, and fifty feet for those among the

For comparison of the work proposed

"Let us begin with Great Britain, ventions in Europe as the most practical which, including Ireland, has an area of A nearly 111,000 square miles, and where convenient size for single sheets would the topographical survey has been going on since about 1784. The scientific work minutes of longitude, making the size of is partly performed by officers of the the sheet, exclusive of margin, about Royal Engineer Corps (382 military, infourteen and a half by twenty-one and a cluding officers, and 1,446 civil assistants half inches. About sixty-five sheets of were on the Ordnance Survey staff in the this size would be required to cover the year 1872), and it is officially known as whole State including a number of fracthe "Ordnance Survey." Its total cost from 1791 to the end of 1864, including The expense of preparing maps on a the military pay of the men employed, sufficient scale to serve for cadastral and was £2,991,624, and may be estimated other municipal purposes should, under up to the present time about £4,200,000. our system of independent municipal The scales adopted are numerous, and in sovereignties, be borne by each municipality whenever its want becomes felt. and even ten feet to the mile. The prin-A number of cities and towns in this and cipal published maps, however, are on some of the adjacent States have already two scales, one of six inches and the provided themselves with such maps, and other of one inch to the mile (1:10,560 it is probable that others might have and 1:63,360). Of England, the map on them provided in connection with the the one-inch scale was begun in 1784 and proposed survey, by defraying the addi- finished in 1869; but the projection emtional expense of increasing the scale, ployed in it was defective, and it is in other respects not up to the present re-The cost of the general survey of the quirements of the country, hence it is State, of which the above general outline now in process of working over and has been given has been estimated by the re-publication. Of the area surveyed on Geological Survey at about \$80.000 to be the six-inch scale, 24,877 square miles had distributed over four years. Of this ex- been completed in England and Wales, and pense the Geological Survey proposes to 27,829 in Scotland, up to the end of 1873, defray one-half. It is not easy to ascer- Ireland, on the same scale was entirely tain in advance the exact cost, which will finished in 1845, and all the sheets, 205 depend upon the minuteness of the de- in number, published without, and about tails and the degree of precision with half with, the hill-shading. Besides the which they are represented. Some of these details, for example, scales, plans are furnished of any district consist of the outlines of woodland, of as called for on the scale of 1:2,500 (about pastures, the minute meanderings of 25 inches to the mile), made by photozincography: but these are not necessarily engraved or published. The map of Another element of variation in expense London is on a scale of 1:1,000, and is is the differences of level between adjacomprised in 821 sheets. The various cent contour lines. For the scale of publications of the Ordnance Survey are moderate prices; but so great as to their number, that the cost of a complete set, as far as published amounts to over £3,000. A great deal of work is prepared for the use of the government on very large scales, but it is chiefly the six-inch and one-inch maps which are of importance to the general public. At the present rate of progress it will require about ten years to complete the survey.

In Belgium the scale adopted is 1:20,-000, the area of the country being about 10,000 square miles, 450 sheets will be required, of which 137 were published up to the end of 1873; the contour lines are drawn at distances of one meter, every fifth one being indicated by a heavier line; the sheets are lithographed and printed in colors, the rivers and lakes being in blue, the lettering and roads in black, the meadows and forests in different shades of green, the buildings in brick-red, and the gardens in carmine.

In Prussia, since 1849, new and more perfect methods have been introduced into the topographical surveys; the plane-table sheets are now published on a scale of 1:25,000, and with contour lines with distances of five, twelve and a half or twenty-five feet according to the nature of the country. The publication of the plane-table sheets was commenced in 1868, and in 1873 120 had been issued. There has also been, since 1841, a general map in process of publication, on a scale of 1:100,000, which will be comprised in some 400 sheets, of which nearly all are These are engraved on copper and have the topography, or hill-shading indicated according to Lehman's system as modified by General Müffling.

In Baden, the new map was commenced in 1874, on a scale of 1:25,000, and with contour lines at ten meters distance. The work is mainly a revision and correction of older surveys and is expected to occupy six years at a cost of about 80,000 florins.

In Saxony, the original survey was commenced in 1780, and completed in 1806 on a scale of 1:12,000, the area of the kingdom being 5,600 square miles. A topographical map was issued in the years 1837-1860 in 22 sheets and on a scale of 1:57,600. A new map was determined on in 1860, and it was completed in ten years; there are two editions of map in 112 sheets on the scale of 1:50,000,

this, one with the line-work only and the other with the hill-shading.

Having now shown what is doing in some of those European states which are, comparatively speaking, rich, densely inhabited, and with moderate areas of territory, let us turn to the consideration of some countries which have only a thinly scattered population and a large area. Russia, for instance, with its enormous territory, just about twice the size of that of the United States, Alaska included, has been for many years actively engaged in prosecuting geographical surveys. The map of Russia in Europe, embracing about 2,100,000 square miles has been under way since 1857, and will be embraced in about 700 sheets, of which 454 had been published in 1872. This is on a scale of 1:126,000. The military map of Poland is on the same scale and is embraced in 57 sheets, all of which are published. Special maps of the Caucasus have also been completed and, recently, a map of Central Asia.

Norway has an area of 123,300 square miles, and a population about that of Massachusetts; that is, our own State is eighteen times more densely populated than Norway. But this comparatively poor country has set itself on having a good topographical map on a scale of 1:100,000, and which will occupy over 200 Those which have already appeared have been highly praised for their execution by competent judges; they are printed in chromo-lithography, like those

of Belgium.

Sweden also, very similar to Norway in respect to area and density of population, has her topographical maps on the same scale (1:100,000) and the work is already nearly half completed, the first sheet having been published in 1860.

The following information in regard to the surveys of other European states, in addition to those enumerated by Professor Whitney, has been gathered from reliable sources. (See Geographical Maga-

zine, Vol. IV., p. 125 et. seq.)

Saxony, in addition to the maps before mentioned, has undertaken a new survey on a scale of 1:25,000 to be comprised in 156 sheets, the elevations to be shown by contours, with crayon-shading to bring out the relief.

Bavaria, having in 1868 completed her

SCALES OF TOPOGRAPHICAL SURVEYS.

EXPLANATION.—Each square is drawn with sides of one-half mile on the scale designated, which is indicated both in the natural way by giving the proportion to nature without regard to any standard of measurement, and by "Inches to a Mile."

U. S. Geological Survey. (Maps of Western Territories.)		$\frac{1}{253440}$, or $\frac{1}{4}$ Inch=1 Mile.	
Massachusetts. (Borden's Map, 1884.)		$\frac{1}{158400}$, or $\frac{9}{5}$ Inch=1 Mile.	
Hungary.		$\frac{1}{144000}$,, or 0.44 Inch=1 Mile	
Russia.	-	$\frac{1}{123720}$, or $\frac{1}{2}$ Inch=1 Mile.	
Prussia (General Map). Norway. Sweden. Portugal.		$\frac{1}{1000000}$, or 0.636 Inch=1 Mile.	
France (General Map). U. S. Coast Survey, (Published Coast Charts.)		$\frac{1}{80000}$, or 0.792 Inch=1 Mile.	
Austria (General Map).		¹ / ₇₅₀₀₀ , or 0.8448 Inch=1 Mile.	
GREAT BRITAIN (First Ordnance Survey.)		$\frac{1}{63350}$, or 1 Inch=1 Mile.	
NETHERLANDS. SWITZERLAND (Mountains). ITALY. BAVARIA. WURTEMBURG. SPAIN. Proposed Survey of Mass. (Public'n Sca	le).	₅₀₀₀₀ , or 1.2672 Inch=1 Mile.	
Denmark.		$\frac{1}{40000}$, or 1.584 Inch=1 Mile.	

PROPOSED SURVEY OF MASS. (Field Sheets.)

30000 Or

2.112 Inch.=1 Mile.

Prussia (Field Sheets)

AUSTRIA

..

BAVARIA ITALIAN STATES.

SWITZERLAND.

SAXONY.

BADEN.

 $\frac{1}{25000}$

or

2.5344 Inch.=1 Mile.

BELGIUM.

ITALIAN STATES (Field Sheets).

France (Department of Seine).

20000

or

3.168 Inch.=1 Mile.

INNER SQUARE.

 $\frac{1}{10500}$, or 6 Inch.=1 Mile.

ORDNANGE SURVEY OF GREAT BRITAIN.

OUTER SQUARE.

 $\frac{1}{10000}$, or 6.336 Inch.=1 Mile.

U. S. Coast Survey. (Field Sheets.)

has a new edition in progress. Also publishes photo-lithographic copies of the original plane-table sheets, scale 1:25,000.

Wurtemburg has also a map on the scale of 1:50,000, of which a new edition

is in progress.

Austria commenced in 1874 a new map comprising 715 sheets, scale 1:75,000, 30' of longitude. The drawings for this map are transferred to copper and the engraved plate is produced by etching. 151 sheets had been published up to 1:144,000. the outlines and lettering in black.

Switzerland has a fine large map beautifully engraved in hachure, but is pre-1:25,000, while the barren mountain regions are shown on the scale of 1:50,000.

The Netherlands issues a new edition of her map on the scale of 1:50,000.

Denmark has a survey in progress, scale 1:40,000.

The great map of France is on the scale of 1:80,000 and is comprised in 267 Contour lines are printed in brown, and water in blue. Some of the departments are being published on the scale of 1:20,000.

Italy is being mapped on the scale of 1:50,000. The field sheets are on the

scale of 1:25,000.

Spain, with a good general map by Coelho, has been engaged since 1858 on a new survey, scale 1:50,000. Each sheet covers 10' of latitude and 20' of longi-The intervals between contours are 10 and 20 meters. Rather slow progress is being made.

Portugal commenced a map in 1856 on the scale of 1:100,000. The earlier published sheets showed the hills in hachures, but of late the contour system with above. intervals of 25 meters has been adopted.

The accompanying diagram is intended scales which have been mentioned. Each nearly all of Cape Cod.

square is drawn to the scale designated, with its sides half a mile in length.

A brief summary of the entire mode of procedure to be used in constructing the proposed topographical maps by the U. S. Geological Survey in Massachusetts will show the high degree of accuracy

that may be expected from it.

The first operation, which has already each sheet including 15' of latitude and been completed by the State Trigonometrical Survey and by the United States Coast and Geodetic Survey, was the primary triangulation of the entire State by which the positions of about one hun-1878. The survey scale is 1:25,000. This dired points in different parts of the State map must now be near completion. Hun- were determined with the highest degree gary covers 198 sheets on a scale of of precision attainable by human instru-The environs of Vienna are ments and methods. This precision has shown in two maps on the scale of 1:12, been tested by measuring two base lines, 500 and 1:25,000. Hills are shown by hundreds of miles apart, and comparing contours having intervals of ten meters, the length of one, obtained by computawith crayon-shading, roads are printed in tion from the other along a series of red, forests tinted in delicate green, and intervening triangles, with its actual measured length. In this way the Coast and Geodetic Survey proved that the amount of possible error in their determinations paring a new survey in 546 sheets, the of the relative positions of the intervenscale of the cultivated districts being ing points, is limited to less than one two-hundred-and-fifty-thousandth part of the actual distances, or less than one foot in fifty miles.

The next step in the work is the secondary triangulation by which numerous points intermediate between the primary stations are located to serve as reference points for the subsequent survey of the topography in detail. It is advantageous to have as many as possible of these reference points and they should be well defined and conspicuous objects. Borden fixed the positions of some 350 secondary objects, consisting mostly of churches and other public buildings. But the forty years which have since elapsed have brought many changes. Many of the churches, etc., have been razed, burnt or removed and other points of reference

have become obliterated.

The Coast and Geodetic Survey also located many secondary and tertiary points and made use of them in preparing the topographical sheets of the narrow strip along the coast, mentioned This strip is, however, wider than usual along parts of the Massachusetts coast. It includes the islands of to show the proportions of the different Martha's Vineyard and Nantucket and

thus completed is about 800 square miles, scheme only needs revision for the purpose of adding town and city boundaries, new roads, railways, mill-ponds, etc., with nometrical problems, the features of the some changes in the outlines of the coast near Cape Cod, caused by the inroads of point occupied may be conveniently the ocean waves.

7,000 square miles, will need to have a the delineation of the topographical de-This secondary triangulation does miles away, and the final determination of the form and size of the earth. Having the primary stations to work from, the precision obtainable, even with the mentally determined, the more accurate ordinary instruments used by civil engineers, is quite sufficient for cartographical purposes, since it exceeds the capabil-

ities of graphic delineation.

The plane table, an instrument which enables the surveyor to construct his map in the field by the graphic method, has been used by the Coast Survey from the commencement of its topographical work, and all its topographers are trained in its use. For cartographical purposes it has many advantages, as it dispenses veying, the measurements of distances science, is entitled to rank among the and angles, the keeping of field notes fine arts. The most skillful topographer and subsequent plotting of the notes by is he who is able to give the real expresprotractor and scale. By this method sion which pervades the face of nature after the trigonometrical points have been corresponding to that which is seen in projected upon the field sheets, other the human countenance, an expression points are marked by intersections of which is the revelation of the forces lines drawn by a ruler with an attached which have acted to produce it. telescope, called an alidade, which being between any pair of points upon it being filled up, and raising the places which are made parallel to that of the correspondlightened by the robberies of the wearing ing pair upon the ground, the intersection of the two lines gives the position of ground movement, which with the surface when the plane table is placed over an lation of materials; and the occasionally undetermined point from which three sudden action of gravity, when the

The area over which the topography is determined points are visible, its position can be ascertained and marked upon the which for the proposed co-operation map by a graphic solution of the threepoint problem. In addition to these and other graphic methods of solving trigoground in the immediate vicinity of the represented by the aid of stadia or telem-The remaining area of the State, about eter rods carried by assistants over the ground from point to point. The distance great many secondary stations fixed by of the rod from the plane table is seen preliminary triangulation to prepare for by inspection in the telescope of the alidade and corresponds to the number of divisions, conspicuously painted upon not require the amount of refinement the telemeter, which are intercepted bewhich is requisite for the geodetic or tween two horizontal hair lines in the primary triangulation, upon which de-telescope. Of course the direction to pends the precision of work hundreds of the point where the rod is held is given at once on the map by the ruler of the alidade.

> The more numerous the points instrushould be the final result, as between these points, the lines of contours, streams, etc. must at last be sketched in by the aid of the eye which requires careful training for the proper estimation of the proper proportions in nature and for their reproduction in the sketch. Our philosopher-poet, Emerson, says "a work of art is an abstract or epitome of the world. It is the result or expression of nature in miniature,"

The converse of this is also true, and with much of the work of ordinary sur- topography, though based upon exact

The geologist studies the active agents placed over the point occupied is directed of natural forces, the ocean waves and toward any point to be located. When tides, the winds, rains and running another known point is occupied and a streams, and ponderous creeping glaciers: second line drawn towards the desired the slow action of gravity, incessantly point, the plane table being in both cases carrying down the great basins of deposit properly "oriented," that is, the direction which would otherwise gradually become the new point upon the map. Moreover, movement, constitutes a complete circu-

strained sheets of rock finally give way, equilibrium with accompanying earthquakes and lava flows. He sees the sculpturing effects of the super-terranean face of the earth into forms which reveal its past history even from those inconceivably remote ages when its living inpresent day.

incongruities in the work of an unskilled topographer whose representations of the surface conflict with the true character of the underlying rocks carrying the characteristic marks of the subterranean agents which have bent and torn them, while lifting them to be shaped into

varying landscape.

The use of the plane table may in some respects be compared to the work of the artist who plants his easel in the field where he can compare his picture with nature as it progresses. It has been adopted by the U.S. Geological Survey, whose topographers find it especially well adapted for mountain topography. The would have the effect of postponing the accuracy of the method is only limited by the conditions of graphic representation, and if the proposed survey of Massachusetts is made, this will be the method employed.

If all the sheets of the map on the proposed scale of 1:50,000 are joined together when completed to make one continuous map it will extend about twenty feet from east to west. Such a sheet would be too unwieldy for ordinary uses, most of which could be conveniently made with the separate sheets. It would be easy, however, to join any required number together, making continuous maps of entire counties, of drainage areas and of preliminary surveys for railways, for water supply and for sewerage of cities, etc.

For schools and academies, a small number of sheets covering the surrounding region, joined together and hung upon the school-room wall, would enable pupils to study the physical geography of their own immediate neighborhood, and to cultivate habits of exactness in observation and comparison.

Plaster models of parts or the whole

colleges, etc., with little difficulty, showand move to new levels of temporary ing in miniature all the inequalities of the surface in their true proportions.

The exact areas, relative positions and differences in heights, of drainage basins, agents which are continually carving the lakes, ponds, swamps and meadows could be found, for sanitary and other purposes by inspection of the maps.

To enumerate, indeed, all the useful habitants, its plants and animals, were purposes of such a series of accurate strangely different from those of the maps would be difficult if not impossible.

The question now presented to the These studies enable him to detect legislature of Massachusetts is whether the State, by co-operation with a trained organization of high character, will secure a survey of this nature at less than half the cost which would be incurred in a

separate undertaking.

On the other hand in case the State declines to co-operate, the Geographical grand and beautiful contours of the ever Division of the U.S. Geological Survey expects to prepare a map at a cost of about \$20,000. The result will be a map having a greater scientific value than the present map, but falling far short of fulfilling the engineering and other State purposes which are attainable by the proposed plan of co-operation.

> Is it not to be feared that this course more elaborate survey until the false economy of the delay should have become evident, even to the most unappreciative minds by repeated wasteful expenditures that might have been avoided by improv-

ing the present opportunity?

Viewed with regard to the welfare of the whole country it would seem that a scheme of national co-operation such as has been outlined above, is worthy of the careful consideration of each of the sev-The amount of eral commonwealths. detail for each State and the consequent cost of the work having been adjusted to its special needs, the conduct of the survey under a skilled national organization would be likely to accomplish far more satisfactory results than if State surveys were independently organized.

The great tower of Norwich Cathedral is in a state which is causing anxiety, and, like the Peterborough Cathedral, may have to undergo important and expensive operations. The wall of the tower near the top is weakened by the introduction of a passage and open ar-cade, and the weight of the spire above is causing settlements in that part. It may, howof the State could be made for museums, ever, be possible to put in the saving stitch.

ON A PRACTICAL SOLUTION OF THE PERFECT SCREW PROBLEM.**

BY PROF. WILLIAM A. ROGERS.

From "English Mechanic and World of Science."

Prof. Rogers said that at the outset it was essential that the term "perfect screw" should be defined. Perfect is a relative term. A piece of mechanism may be termed perfect when it meets all the requirements of the purpose for which it was constructed. After describing the errors to which screws are subject as being an error in the total length, the pitch of the screw for even revolutions not being uniform, and the fact that there may be a gradual increase of pitch up to a certain point, and then a diminution until the amount of decrease is equal to the previous amount of increase, he detailed the most important failures to make satisfactorily perfect screws, and continued:-An order was received from Prof. Wm. A. Anthony for the construction of a dividing engine for the Physical Department of Cornell University. Upon accepting the order, a shop was fitted up in Boston with tools of the best quality, chiefly from the establishment of Pratt and Whitney, and Mr. Ballou undertook the construction of the engine, mainly from his own designs, and of the screw which is its essential part. The completed machine was shipped in just 35 weeks after the actual commencement of the work; and the screw, which will be presently discussed, was cut and ground in 27 hours from the time the first tracing of a thread was made. It was at that time practically perfect for about 20 inches, and nearly as perfect as it afterwards became by the process of grinding adopted. Notwithstanding the fact that the work was done upon a common lathe in which the errors of the leading screw were enormously large, the result showed that the method employed was based upon correct mechanical principles, and was entirely feasible.

This method can be described in a very few words.

Let the reader hold clearly in mind the following. There are:

1. an ordinary lathe, the ways of which have been made as nearly straight as possible.

2. A shaft between dead centers which maintains a cylindrical form during every revolution and every part of a revolution.

3. A microscope provided with Tolles' opaque illuminator for viewing opaque objects, attached to the carriage moved by the leading screw of the lathe.

4. A graduated bar mounted independently of the carriage, with subdivisions which are multiples of single threads of

the leading screw.

5. A slide moving parallel with the leading screw, by means of a very short and firmly mounted micrometer screw of comparatively large diameter and attached firmly to the carriage. The toolpost is secured firmly to the secondary slide.

6. A mechanical means of determining when the leading screw has made a

complete revolution.

The method of proceeding was as follows:—The graduated bar having been leveled up and set parallel to the axis of the screw to be cut, the micrometer of the microscope was set upon the initial The lathe was then started with the leading screw "in feed." After the screw had made, for example, nearly ten revolutions, the lathe was stopped and the remainder of the even revolution was completed by hand manipulation. deviation of the micrometer line from the corresponding graduation upon the bar was then measured in terms on the screw head of the secondary micrometer screw. In this way the errors of the leading screw with respect to the graduations of the standard bar were determined and written down upon a strip of paper pasted to the vertical face of the bar. The carriage was then started again with the cutting tool in operation, and by means of a rough pointer, the micrometer screw

^{*} A paper read at a recent meeting of the American Society of Mechanical Engineers.

working the secondary slide was fed work out the periodic errors of the screw, mined. Hence, when the even revolution was completed, it would be found that operation was kept up until the screw was finished.

cutting, it was found:

screw corresponded nearly with the the oil, which in this case would be symlength of the line standard from which it metrical with respect to the axis of the

Second.—That there were at many points minute irregularities of pitch, due to the fact that the application of the corrections intermediate between the main divisions had not been exactly made.

removal of these irregularities by grinding with a brass nut was a complete success. As had been predicted, they were small errors had been introduced in the for the most part removed after an hour's mean time at other points, through a slight

ing upon the / screw remained constant, the line under ameter still a little less than before. This constancy under half-inch objective for the most part in eliminating the errors was maintained for about 20 inches, which had been introduced during the Then the nuts began to separate, and the second week. Throughout the entire separation continued until the maximum operation of grinding, reversals were deviation amounted to about $\frac{1}{5000}$ of an made every hour both of the halves of the inch; but near the end the nuts came nut and of the screw upon its centers. back to their first relation.

errors, together with what errors might perfect screw, there remained the diffiremain which were a function of one re- culty of using it so that it should remain volution of the screw, the following meth- perfect. In using a comparatively short od was employed. The grinding nut was nut on a long screw, the screw under the made in halves, in such a manner that a ordinary conditions of use was unequally constant relation was maintained between worn at different places in its length, the the halves, both in their normal and in result being that the originally accurate reversed positions. By grinding the screw soon became full of inaccuracies. screw, first with halves of the nut in their Were it possible to use a nut of a length normal relation and then in reversed re-equal to that of the screw the accuracy lations, the tendency was to continually of the latter might be maintained. Imag-

either forward or backward, in accord- with the exception of minute errors ance with the corrections before deter- which were transferred from the screw to the nut during the operation of grinding.

In order that the nut might grind withthe line of the bar would be nearly under out disturbing the general relation bethe cross wire of the microscope. This tween the threads, a cast-iron cylinder with a center at the bottom was filled with the best sperm oil, and the screw At the completion of the operation of was mounted vertically upon this center. At first two broad fans were attached to First.—That the total length of the the nut in the hope that the resistance of screw, would be sufficient to drive the nut upon the screw. As this movement was found to be too slow, a guiding rod was used.

The grinding process was continued for three weeks, and the results obtained confirmed previous experience. At the Third.—That the crucial test of the end of the first week the maximum error of $\frac{1}{5000}$ of an inch had been reduced about one half, but it was found that transfer of the errors of the screw to the The method of testing was as follows: nut itself and from thence back to the Two half nuts with projecting arms rest-screw. Near the end of the second week shaped way the screw was clearly less perfect as a were first placed at a fixed interval apart, whole than at the commencement of the A microscope was mounted on one nut and operation of grinding. Mr. Ballou then coincidence was made between the microscope and a less than that of the screw. Within a few line drawn upon the upper surface of the hours thereafter a decided improvement other nut. It is obvious that if the rela- was observed. A new nut was made at tion between the different threads of the the end of the second week having its dithe microscope would remain constant. During the third week the gain consisted

Prof. Sweet, in the course of discussion, In order to eliminate these residual said that having obtained a practically edge, but with small local inaccuracies along its length, and then trying to remove these inaccuracies by grinding with a short and perfectly accurate straight be constructed to carry the canal over the edge, and you have a fair idea of the conditions existing in the use of a short nut and a long screw. The accurate straight edge must be as long as the one it is used to correct. He had often thought that, in the lead screw of a lathe for instance, by removing some of the threads on the parts of the screw that were used the least the tendency would be to a better preservation of the accuracy of the screw, but as in many other things, he had never had the courage of his convictions in a sufficient degree to do what he thought was right.

ENGINEERING NOTES.

The report of the directors of the Panama Canal Company on the present condition of the works states that the number of men employed in May, 1884, was over 19,000. It is calculated that the excavations amount to 110,-000,000 cubic meters, in addition to 10,000,000 cubic meters of earthworks in altering the course of the Chagres. Up to the end of April, 1884, the total amount of work done is represented by 5,243,302 cubic meters of earth removed. Until January 1st, 1884, however, the real work of cutting the canal had scarcely fairly begun, and of the total of 5,248,302 cubic meters of earth removed, nearly half, that is to say, 2,482,768 cubic meters have been removed in the first four months of the present year. In the total of 120,000,000 cubic meters of ground to be excavated, 40,000,000 will be taken away by means of dredgers. The projector says there can be no doubt of the canal being open for navigation before the close of

The proposal to construct a ship canal across Ireland is again to the fore. The Dublin Freeman's Journal has published particulars of the project for constructing a ship canal across Ireland, which it assures its readers is a reality, and has been warmly espoused by influential people in England. "Elaborate plans and surveys have been made at considerable expense, and have been submitted by Captain Eads, the American engineer. The proposed canal would be 127 miles in length, and would contain thirty locks. For ships of 1,500 tons the cost would be £8,000,000; for ships of 2,500 tons £12,000,000; and for ships of 5,000 tons and npwards £20,000,000. If built on this scale the canal would be 200ft, wide on the surface and 100ft, at the bottom. The passage through the canal would be effected by a system of towage, and it is estimated that the passage of a ship from Galway Bay to Kingstown would occupy between twenty-four and thirty-six hours. Vol. XXXI.—No. 4—24

ine a long and nearly accurate straight which the ships would be carried in cradles, which could be constructed for £10,000,000, is proposed, by which the duration of the passage through the island would be reduced to twelve An immense aquednet would have to Shannon at Banogue. It would be over three miles in length, and would be one of the most difficult and costly works in connection with the undertaking."

> The producers of petroleum on the western shore of the Caspian Sea have been contemplating seriously the laying a pipe line entirely across Persia to the Persian Gulf. If this were done they say that they would have the Asiatic market to themselves; which is not so certain, however, because there would be no traffic to the Persian Gulf port for vessels taking petroleum to India, China, &c., from it. A pipe line would have to be something more than 700 miles long to reach the coast, and as it would for a long distance pass through a territory of savage Kurds and other nomadic tribes, it is feared that it could not easily be kept in operation.

> HE preparatory measures for the junction of the sea of Aral with the Caspian Sea have reached a further stage by the return to St. Petersburg of the Russian expedition which has been surveying the route. The Russian has been surveying the route. Government was so convinced of the important nature of the proposed water-way that General Gluchowsky, the originator of the idea, was sent at a cost of nearly £100,000 with a corps of experts and engineers to make the necessary investigations. The results of this step have not been made public, on the ground of their being under examination by a commission. It is, however, concluded in some quarters that the silence of the official press indicates the non-fulfillment of the original expectations.

Bridges and structional ironwork have been in fair demand during the past six months, and Messrs. Matheson and Grant in their "Engineering Trades' Report" say: "Prices have fallen only in proportion to the slightly lower cost of iron. The ironwork required at home has been mainly for the widening of railways and the extension of existing stations. The application of machinery to the manufacture of iron structures has been much improved during the last few years; portable as well as fixed hydraulic riveters are now almost universally used, and multiple drills form a more important part of factory equipment than formerly. The English system of riveted connections is still preferred to the American plan of links or 'eye bars' with pin connections, and though bridges according to the latter method come into competition with English bridges in South America, and have even been imported into the Australian Colonies, the English riveted bridges are preferred where stability and permanence are valued. Steel is becoming more used as its price approaches that of iron. Besides the Forth Bridge, which will require about 10,000 tons of steel per annum for the next four years, steel bridges over the Hoogh-An alternative scheme of a ship railway, on ley and the Indus are being made for the In-

dian railways, and will do much to render engineers and manufacturers acquainted with its use. In London, the railway bridge over the Thames at Blackfriars is being doubled, the South-Eastern Railway bridge at Charing-cross is to be widened, Hammersmith Suspension should be capable of retaining an edge suffi-Bridge is to be strengthened, and a new iron cient to cut through tough turf and dead grass. bridge is to be built at Battersea. The long But most of the "cast steel" spades in the

IRON AND STEEL NOTES.

Bessemer Steel for Engineers' Tools.—
How nearly Bessemer steel can be brought to crucible in its usefulness for tools is a matter than which there are few more important to the machinery engineer. The advance of the Bessemer metal in this respect means to him a considerable saving of money. It may not, perhaps, be generally known that the Barrow Hematite Steel Company is doing a good deal in the production of Bessemer steel for uses hitherto served by crucible steel. In addition to its usual out-turn of heavy steel, in the form of rails, blooms, tires, &c., the company is producing upwards of 1,000 tons per week of special steel, which is being worked up in various parts of the kingdom into all the following forms:—Roll-turning and lathe-turning tools, chisels, files, shear blades, rail drills, rail punches, shear steel for welding to iron, miners' drills and tools, picks, shovels, hand hammers, roller bar and cotton spindles, locomotive engine, wagon, carriage, coach, and furniture springs, bolts, nuts, rivets, pit-ropes, telegraph, crinoline, and corset wire, umbrella frames, wire for musical instruments, and the like. Nor has cutlery itself been found too hard a test; for this special steel has been made even into razors with decidedly good results. Touching the extent to which the articles answer, it may be mentioned that a 1-inch pit chain, made from a soft sample of this special Bessemer make, withstood a breaking load of 35.63 tons; elongation, 6 inches or 18 inches. The welding had been done by a smith not accustomed to chain work. This is very encouraging to machinery engineers, with whom Bessemer steels are gaining favor to the supplanting of cheap cast steels.

OBSERVATIONS ON HARDENING.—Too many of the so-called steel articles sold in the market are either made from steel incapable of being hardened, or are not hardened at all. Good cast steel can be hardened and tempered so as to receive and retain an edge. This is not required of table cutlery generally—only of the carving knife—but it is required of the hand saw and the buck saw, of the spade and the manure fork, of the scissors and the pocket knife. Saw blades (so far as the writer has tried them) are not hardened; they will not reas they come from the rolls and the slitting machine, with no pretence at hardening or tempering. But they are stamped "cast steel," to get good hardened and tempered saw blades, they offer as to haulage power.

even at a much higher cost than that of the soft plates, the teeth of which can be bent by thumb and finger, and the set of which is removed by sawing through an inch thick spruce A spade is only an enlarged chisel; it board. proposed bridge across the Thames by the market can be sharpened as readily by drawing Tower will probably soon be built." the edge cold under the hammer as by the grindstone. The edge never breaks, but batters and bends. The trouble with almost all the cast steel tools put ready made on the market is that they have never been hardened. Cast steel unhardened is as soft as wrought iron uncasehardened. A cast steel hammer became so indented on its face by driving nails during one season in jobbing that it had to be reground and polished. Yet the hammer was of steel capable of being hardened, as was proved by its being subsequently hardened and drawn to temper. It is quite possible that the reason why many of these articles prove to be soft is, not that the material is not good, but that they have never been hardened. Brightened steel that has not received a hardening may respond in after-heating to several of the tempering colors; and this is probably one reason why common steel articles are not thoroughly hardened. It is not uncommon to see a forger or temperer heat a piece of cast steel to a very low red—a red that shows only in the shadow and then brighten and draw the temper to color, when after-trial proved that the steel had never been hardened. Indeed, the dull red that some smiths use for hardening such tools as cold chisels and other low-grade tools is that at which a red annealing may take place, the piece being heated to a dull red and plunged into water. The first requisite in making a cast steel tool into a working tool is to harden it. After its hardness is proved then it may be tempered to the condition required. no intermediate process of properly tempering between absolute hardening and subsequent drawing.

---RAILWAY NOTES.

The whole extent—75 miles—of the Coude d'Eu Railway, in the Province of Parahyba, Brazil, constructed by Messrs. Wilson, Sons & Co., was successfully opened for traffic on 4th inst., this being before contract time.

I is now some twelve years ago that Messrs. Merryweather & Sons, of London, constructed their first steam tramway engine for the late Mr. Grantham. Since the failures of that time the economy and practical value of steam on tramways have been gradually proved in several parts of the world. The measure of success now obtained may be gathered from tain "set" nor hold edge. They are gummed the fact that Messrs. Merryweather have received an order for fifteen of their tramway locomotives for use on the North London tramways. This tramway company has waited unand that probably satisfies the public; but there til experience has improved tramway engines are mechanics who would pay something extra sufficiently to add economy to the advantage A BOUT 94 per cent. of the double mileage of the railways in England and Wales is now worked on the absolute block system, and the greater portion of the single lines is under the same control, in addition to the train-staff system. In Scotland, the double mileage worked by the absolute block is 90 per cent. of the whole, and in Ireland, 22 per cent.

The active interest taken by the Austrian Government in the construction of rail-Government in the construction of railways in Bosnia and the Herzegovina is being further illustrated by the proposal for a line from Metkovic to Mos'ar, following the right bank of the Narenta, and designed to facilitate commerce while also serving useful strategical purposes. Metkovic is at present a point of junction between the steamboat service on the Narenta and the land transports. After the regulation of the stream it is expected that large vessels can reach this point. There are important coal deposits at Mostar. The total length of the line is $26\frac{1}{2}$ miles, and the difference in altitude between the terminal points about 200 feet. The gauge is fixed at 29.92 inches so as to correspond with the Brood-Serajero line. The permanent way will consist of steel rails 3.54 inches in height, and weighing about 34 lbs. per running yard, the maximum gradient not exceeding 1 in 300. There is a tunnel about 150 yards long, and various cuttings through The three stations are rocky ground, &c. principally intended for supplying water to the engines, as the country is thinly populated. The line is estimated to cost £170,000. It is in view to prolong the line to Serajevo, and a branch from Metkovic to Ragusa is also spoken of by the Deutsche Bauzeitung.

OME idea may be formed of the traffic on English railways from the Civil English railways from the following facts: -Through Farringdon Street Junction of the Metropolitan Railway 1,800 trains pass in twenty-three hours every day. There are four lines of rails, used by the Metropolitan, Great Northern, Midland, London, Chatham, and Dover, and Metropolitan Extension Companies. Through Watford Junction, on the London and North-Western Railway, 233 trains pass every day. This gives something like one in every four minutes of the twenty-four hours. At Cannon Street station, on the South-Eastern line, the number of trains using the station is 750 in one Through Clapham Junction the London and South-Western Railway had, in the year 1877, on an ordinary week-day, 656 trains, while on the Derby Day of 1876 no less than 1,023 trains passed through this junction. The number is now over 1,000. The total number of passengers conveyed in 1883, exclusive of season-ticket holders, was—first-class, 36,387,177; second-class, 66,096,784; third-class, 581,233,-476; total, 683,718,137; and season-ticket-holders, 180,000,000; total \$63,718,137. Of minerals there were conveyed 189,485,612 tons; of general merchandise, 76,897,356 tons; number of miles run by passenger trains, 139,545,464; number of miles run by goods and mineral trains, 129,351,774; total miles run, 268,897,-236; miles of railways, 18,668; number of persons employed, 367,660.

THE American Consul, Mr. Lyell T. Adams, at Geneva, writing on the subject of international railway communication, states that any account of the commercial position of Switzerland at present would be incomplete without some reference to the great change impending on the completion of the new lines of international communication, whose effect will be to make her a commercial, as she already is the geographical and hydrographical, center of the Continent. Nothing has isolated her, hitherto, but the altitude above the sea level, now overcome by the Brenner Railway, and the tunnels of the Mont Cenis, the St. Gothard, and the Arlberg recently opened. By these routes the extremities of Europe are brought into direct relations, the meeting point of all lying upon Swiss territory, with the exception of the Mont Cenis. This line crosses Upper Savoy, which, by the treaty of 1815 forms part of the Swiss neutral territory, to be occupied in war by the armies of the Confederation. One of its main feeders is the West Swiss Railway, from Berne to Geneva, and much of its traffic is likely to be diverted by the projected tunnel under the Simplon. What effect, adds Mr. Adams, this reconstruction of the European railway system will have on the fortunes of Switzerland, it is as yet too early to conjecture.

HE construction of the Corinth Canal seems to have tended to increased activity in railway construction in Greece. A railway is being constructed in the Peleponnesus, starting from the Pyræus, which is the port of Athens. The station at Athens is about 1,500 feet in length and 130 feet in width, being near the Academy of Plato. The Kepissos is crossed by a bridge 90 feet in length, and the railway then traverses the north-western plain of Athens to Kameteron, following in a northerly direction the base of the Parnes mountain, subsequently penetrating through the narrow pass of Phylæ, and proceeding through the villages of Charia to Eleusis. The further portion of the railway from Eleusis to Megara was expected to be opened about the present time. The portion of the line from Megara to the Isthmus of Corinth presents the difficulty of a track overhanging the sea at a height of about 190 feet for a distance of nearly six miles, this romantic locality being known as the Scirronic Rocks. The completion of this portion of the line will hardly be possible before a late period of the Autumn. At Corinth the line divides the southern portion terminating at the cities of Argos and Nauplia. The western line follows the coast of the Gulf of Corinth, and goes through Ægium-Vostizza-to Patras. From that point it extends along the west coast of the Peloponnesus through Achaia, Gastuni, and Kalakolon to Pyrgos, in the vicinity of Olympia. The whole district traversed by the railway is thickly populated and in a good state of cultivation, the gain to local commerce being enhanced by the fact that there are scarcely any practicable harbors at that part of the coast.

THE LARTIGUE BALANCE RAILWAY.—A correspondent writes to the *Times*: Already a railway exists in Africa, working several miles, for the conveyance of the alfa plant

paper, which may possibly prove of good service in Egypt. This is the elevated single-rail system invented by M. Lartigue. It is said to be much cheaper in material, in working, and in the rapidity with which it is constructed than any other system. Although, as an agricultural railway, specimens had been exhibited and had gained medals at the exhibitions of Amiens and Amsterdam last year, the railway was first shown with electricity as the motor at the Palais de l'Industrie this spring. At the time I gave particular attention to the subject from an agricultural point of view, and obtained from the inventor himself much information concerning it. In due time it was seen in working order in the exhibition, and became quite a center of attraction, being visited by the president and many of the official notabilities. Messrs. Siemens had supplied, at eight days' notice, a very effective electrical motor, which, attached to light cars running on grooved wheels over a single bar of iron suspended about three feet from the ground, drew along goods and passengers in a very satisfactory manner. So light was it that an American general with me, who had put 250,000 men in the field, pulled along with his simple strength about fifteen cars, with the observation, "These trucks are a going concern." The sections of the rail are wonderfully light, the rail, bar, and standards weighing only about 65 lbs., and the cars for goods 75 lbs. A couple of workmen can set up several hundred yards of the line in a single day. Curves are made by simply bending the rail bar, and a few plain contrivances are applied which meet all the ordinary railway transit exigencies that occur. It is reckoned that the haulage power necessary to move the load on this system is 30 per cent. less than is required upon ordinary double rails. Riders of bicycles will readily understand this. The rail is, in fact, regarded as the backbone of an animal, and the burden is balanced or distributed on either side, hanging baskets or frameworks carrying variously shaped vessels forming cars which run on the center wheels. The center of gravity, being below the point of suspension, is not readily disturbed, so that the difference of half a hundredweight on either side only gives a slight "list" to the load without increasing the friction. Trusses of straw, baskets full of produce, vessels for oil, wine, &c., and frameworks for minerals were shown in various cars. and a passenger car to carry four or six persons was exhibited. This display was at the end of February. On returning to London with many detailed plans and illustrations of the system, I made a point of showing them in various quarters, among others, to the chief engineer at the General Post Office, and to scientific and agricultural friends, some of whom referred to the principle of the saddle-back or balance railway as being old. However, the detailed designs, iron standards, and models of carriages were recognized as novel and practical, while the electrical locomotive was undoubtedly new. Patents, in fact, have been obtained in France, England, America, and other countries. being the position, I was not astonished on revisiting France last week to find Lartigue's railway, with its single bar, occupying space

at most of the Concours Regionaux. I saw it at Orleans this week attracting notice; and at the Rouen Exhibition, just about to commence, carriages for passengers on a large scale will be shown such as I have this afternoon examined at the foundry at Grenelle. The system is under the consideration of the French Government as one especially suitable for military purposes, forming a flying force from its portability. Along the iron standard, 3 feet or $4\frac{1}{2}$ feet high, runs an iron bar, in which is enclosed and protected a telegraphic wire. Probably soon our own Government will duly consider this new system for military purposes, telegraphic and parcel communication. Our first Commissioner of Works, Mr. Shaw-Lefevre, has already evinced an interest in this French invention, and certainly it is time the system should receive scientific notice on our side of the Channel, which it cannot fail to do if you can afford notice of it in the *Times*. For warehouses, farms, contractors' works, mines, &c., the cost of this system is put at about 4s. 6d. a yard, and carriages of various forms are offered at from 24s. to 48s. each. The estimate given to a mining company in Ireland which has made enquiries for the construction of over two miles of line, to carry 200 tons in ten hours, is, inclusive of thirty carriages, only £1,350—a cost much below that of the miniature railway, running on two rails. The electric locomotive machine of Messrs. Siemens is divided into two parts, disposed and balanced on either side of the rail, following thus the general principle of the system. The motor is a dynamo-electric machine, with the current continued in circuit in connection with a fixed generating machine, and is so contrived that the oscillations of transit do not break the contact. The algebraic formulas and technical descriptions, in which engineers revel when forming comparisons of one system with another, may here be omitted, with the remark that, as French experts have worked out their sum, the results in favor of a railway running on a single bar are such as to commend it to the English public for practical consideration.

ORDNANCE AND NAVAL.

THE SEA-CELL AS A POSSIBLE SOURCE OF DAN-GER IN TORPEDO-EXPERIMENTS. By H. MOORS.

In considering the cause of a fatal accident, due to the explosion of a torpedo in an experiment conducted on board H.M.S. "Cerberus," the author was led to the conclusion that though in this case it was "not proven," still the electrical action set up between the zinc plate of the torpedo case serving as earth for the firing-current, acting as one pole of a battery when immersed in the sea, and the iron hull of a ship with which the firing-line could accidentally make contact, acting as the other pole, might in certain cases be sufficient to ignite the fuse. A battery thus formed would have no resistance and an electromotive force of about 0.514 to 0.564 volt; the platinum fuse ordinarily adopted has, according to the table given in the "Chatham Instructions in Military Engineering," a resistance of 0.325 ohm cold,

and 0.74 ohm at the fusing-point, the current sufficient to fire a charge being 0.75 ampere; a more sensitive detonator has a resistance of about three times the former, and requires only 0.32 ampere; the conducting wire used in the experiment was such as to give 126.8 yards to one ohm. From these data it results that the total resistance in circuit for firing the ordinary fuse with such a sea-cell would be 0.752 ohm, and allowing for the increase of the fuse's resistance with temperature, it would certainly explode with $44\frac{1}{2}$ yards of such a conductor in its circuit; and, owing to the uncertainty of the data adopted, a far greater margin of safety would be required. Experiments to test this theory were carried out by Messrs. G. S. Caldwell and G. Smibert, of the Post and Telegraph Department (the former was the first to propose the above theoretical deduction as the cause of the accident), and though unpublished, their results were placed at the author's dis-The experiments were made ou board H.M.S. "Malwa;" a zinc plate, 7×3 feet, was lowered clear of the hull, and a small portion of the rail well cleaued, with which the conductor was put in contact, by this means eight fuses of the regulation pattern were exploded through lengths of wire varying from 10 to 41 yards (175 yards of this conductor had a resistance of 1 ohm). An exposed surface of copper in connection with the iron, as was supposed to be the case on the "Malwa," would give a higher electromotive force than iron alone. The conclusions point convincingly to the possibility of accidental ignition from such a cause, and the necessity for due precautionary measures to prevent any such accidental contact in all torpedo experiments.—Abstracts of Association of Civil Engineers.

BOOK NOTICES.

PUBLICATIONS RECEIVED.

From Mr. James Forrest, Secretary of the Institution of Civil Engineers, we have received the following papers:
Emery Wheels and Emery Wheel Machinery.

By Walter Osmond Rooper.
The Storage and Shipment of Grain. Woodford Pilkington, M. Inst. C.E.

Experiments ou Transmission of Heat. By Gustav Adolph Hageman.

By The Basic Open-Hearth Steel Process. Thomas Gillott, M. Inst. C.E.

The New York, West Shore and Buffalo Railway. By Peter Chalmers Cowan.

The Comparative Value of Labor in Different By Charles Ormsby Burge, M. Countries. Inst. C.E.

TADIA SURVEYING. By ARTHUR WINSLOW. Van Nostrand's Science Series, No. 77. New York: D. Van Nostrand. Price 50 cents.

Since good authorities have determined that with proper instruments the stadia method of measuring distances is as reliable as average chaining there has been manifested a strong disposition to adopt the method in quarters where it was heretofore unknown.

The inquiry for a suitable guide to the method

had become quite a brisk demand before Mr. Winslow's essay was printed in the pages of VAN NOSTRAND'S MAGAZINE.

The formulas and tables are such as are employed on the Geological Survey of Pennsylvania, and they form a part of the official

It is rare that so complete a treatise on the theory and practice of a method in surveying is found in so small a volume.

Besides the stadia tables the book is furnished with a table of logarithmic sines and tangents to four places of decimals.

Par Gaston Plante. Paris: Revue la Lumiere Electrique. Price \$3.50.

The importance which secondary batteries and accumulators have of late assumed has invested with a new interest the labors of M.

The treatise before us is divided into six The first treats of accumulation and transformation of electric energy by aid of secondary currents. The second part treats of applications. The third part contains "Effects of Currents of High Tension." The fourth part, "Analogies between the Effects of High Tension and some Natural Phenomena." In the fifth part is described the Rheostatic Ma-chine. The sixth part discusses the analogies between electric phenomena and some purely mechanical effects.

The book is beautifully printed and illus-

TREATISE ON EARTHY AND OTHER MINER-ALS AND MINING. By D. C. DAVIES, F. G. S. London: Crosby, Lockwood & Co. Price \$5.00.

This book is devoted to an account of the more important minerals, their properties, localities and mining. The so-called useful aud the precious or uoble metals-in short, all those which are commouly used in the metallic state—have been discussed by the author in a previous treatise ou "Metalliferous Minerals and Mining."

The minerals to which considerable space is given are, first, silica, and the chief combin atious of alumina, maguesia and lime. Then in order come salt, sodium uitrate, borax, baryta and gypsum. Phosphate of lime is discussed through four chapters. Three chapters are given to carbon and one to sulphur.

What the author calls metallic minerals are represented by arsenic, cobalt, molybdeseum,

antimony and mangauese.

The illustrations are numerous, but rather poor, and as the above schedule indicates, the work is manifestly incomplete.

ORESTS AND FORESTRY OF NORTHERN RUS-SIA. By JOHN CROUMBIE BROWN, LL. D.

London: Simpkin, Marshall & Co.

In this, Dr. Brown has contributed another addition to his long list of treatises on Forestry. In this essay, as in the one immediately preceding it, there is to be found a large fund of information regarding the physical geography of the area described.

Part I. is devoted to a general description of

the forest lands, embracing besides the northern portion of Russia proper, Lapland, Nova Zembla, and regions still beyond.

Part II. deals with Forest Exploitation, and relates to all the Forest Industries, including the manufacture of tar, turpentine and vin-

egar.

Part III. gives briefly an account of the Topography, Fauna, Flora and climate of the region—in short is a concise treatise on Physical Geography of Northern Russia.

M EMORIAL OF ALEXANDER LYMAN HOLLEY, C. E., LL. D. New York: American

Institute of Mining Engineers.

The reader will find in this memorial a skill-fully-arranged summary of the literary and practical works of Mr. Holley. The book is pleasant reading, not alone from the fact that much of it is the composition of a near friend who wields a graceful pen, but also from the fact that the most earnest praise in the volume is from the foremost men in Mr. Holley's profession; men who were the best possible judges of his worth and his work, and who regard with evident pride the record of their compatriot.

At the memorial session of the American Institute of Mining Engineers, held a few weeks after Mr. Holley's death, the following summary of the qualities of their deceased member was expressed by Hon. Abram S. Hewitt: "I think that even now, so soon after his departure, we can assign him to the place which he will hereafter occupy in the history of mechanical industry-a mechanical engineer of unerring judgment, an inventor of the true means for great results, a lover of his race, who subjected his science, his talents and his labor to the good of his fellowmen; and he will live in the memory of those who knew him, and in the grateful recollection of those who will come after him, for many a generation."

A list of Mr. Holley's literary works forms the seventh chapter of the memorial. The earliest mentioned paper bears the date 1850, three years before Holley graduated at Brown University. Many short articles are only referred to collectively in a foot note, but enough is clearly specified to prove that Mr. Holley was one of the most industrious of scientific men. He was the first editor of this Magazine, relinquishing it at the end of the first year on account of the pressure of his practical work.

OUSE DRAINING AND SANITARY PLUMBING. By Wm. Paul Gerheid. New York: D. Van Nostrand. 2d edition, revised 1884. Van Nostrand's Science Series, No. 63. Price 50

cents

The author is chief engineer of a company actively engaged in pushing improvements in this special line. The position is eminently adapted to produce a valuable book, if not too partisan. We do not observe the latter fault. On the contrary it appears remarkably fair in its enumeration and courses of the various devices in use in all the divisions of the subject from "Wash Basins" to "Trap on basin Drain."

He has managed to say a good deal on this vitally important subject in a 12mo book of 240 pages. The illustrations are peculiarly aggre-

gated on larger sheets than the pages, and folded in. The inconvenience is more than balanced by the facility it affords for comparison. There is danger that with much use such illustrations will be detached, or at least mutilated. But it is a consoling reflection that the end is progressing with such strides that few will care to study these sections, except as curiosities, ten years hence.

The importance of being able to determine at moderate expense, in all situations, whether there are any considerable openings in the drainage pipes in a house can hardly be over estimated. The test of filling the interiors with a strong and marked odor has been long practiced by plumbers, and can be applied by any householder. It is described on pages 62 and

63.

An enumeration of five separate points on page 68 serves as a text for much of the succeeding portions. The book details, down to the latest steps of progress, how to attain these

several points.

We pronounce this work, as now revised, the most practically important of this entire fifty-cent series. It is the most likely to do good by its extensive circulation. The community owes a debt to the author and publisher for disseminating this kind of information.

THE PRINCIPLES OF VENTILATION AND HEATING, AND THEIR PRACTICAL APPLICATION. By JOHN S. BILLINGS, M. D., LL. D. (Edinb.), Surgeon U. S. Army. The Sanitary Engineer, N. Y. 1884. Price \$3.00.

Ever since the tailless animal reached the stage of refinement at which he commenced to avail himself of a covering of leaves, grass, turf, logs or snow, to defend himself against the heat, wet or cold, the question of how to live at the bottom of an ocean of air and have enough of it to breathe, has been before him.

Ever since Prometheus brought fire from heaven, or mankind some other way invented artificial warming, he has been confrorted with the further difficulty—how to make fire available to ventilate; or, in many cases, has been obliged to "give it up," on the simpler problem—how to ventilate sufficiently in winter without too much cooling his building. This book is a valuable contribution towards its solution. But it shows that it is not yet solved.

Some forty years ago a wealthy gentleman of this city constructed a stable with an air passage from each stall out through the roof. His horses had colds all the time, till he closed

them.

The Klamath Indian along the line between California and Oregon, in composing himself and his heterogeneous family for sleep in cold weather, lets the fire go entirely out, and then tightly closes the only orifice in his small earth hut. Exact scientific calculation, writes a friend of ours who was at one time surgeon at Fort Klamath, shows that they will all be dead at ten minutes before three. They perversely live and flourish.

This book is eminently a collection of facts, but these two facts are not in the volume. The chief fault one finds in reading it, with a desire to learn the latest, or rather the best plans, is the

abseuce of a clear statement of what the author recommends. He says, in substance, the amount of ventilation practicable with efficient warming depends on the expense which the owner is willing to incur in the construction, and in the subsequent fuel bills, a truism which no one can gravely dispute; but when we ask how to spend money, with tolerable assurance that the ventilation will be right so far as it goes without interfering with the warming, if the answer is there, it is not as conspicuous as we would like to see it. The United States Government expeuded liberally in ventilating the magnificent room—the House of Represeu-

tatives in Washington.

Possibly some may consider the book better for omission of any recommendation. We do not. When one is familiar with the subject we deem it not quackery, but the opposite, the conclusion of one who has given much well-trained thought, observation and experience to his subject. To tell us how, it is due to the public. The preface tells us the object of the writer is "to present the general principles which should guide one in judging of the merits of various systems of, and appliances for, ventilation, more especially as applied to large public buildings." Engravings and descriptions are given of the provisions for warming

and ventilating many buildings.

The elaborate description of steam-heating pipes, faus, distributing passages, and exhausting shafts in Mr. C. N. Dickenson's house, the Fifth Avenue Presbyterian Church (Dr. Hall's), Metropolitan Opera House, Madison Square Theatre, Union League Club, and Columbia College, New York; the south wing United States Capitol, and Barnes Hospital at Old Soldiers' Home, Washington; the House of Lords and House of Commons, London; Grand Opera House, Vienna; St. Petersburg City Hospital, Russia, and other buildings of less note, with his evidently fair statement of the remaining difficulties in most or all the cases, leave one with a painful sense of the little, instead of the much, which is known about ventilation. At Dr. Hall's church, he writes (p. 111); of Mr. Dickenson's house, our author writes (p. 69); of the latest and best result in the U. S. Capitol.

Our author gives with faint approval the leading features of the Ruttau system, a system devised by a wealthy Canadian, the late Henry Ruttan, who lost some members of his family by lung diseases, and spent the rest of his lifetime in devising and carrying out a plau of natural ventilation, excellent for dwellings and all buildings not crowded. We esteem the Ruttan system. Pouring the air in at the top and taking it out at the bottom deserving

much more attention.

This book is valuable, immeusely valuable. Its work is in a liue beyond mere dollars and cents. Dr. Billiugs as author, and the Sanitary Engineer proprietors as publishers, are doing missionary work, in spreading light on this subject. If the light is foggy, it goes to show if any proof were needed that this subject is one which needs this book, and much still further skillful observation, experiment and successful practice with a still further wide-spread publication of the result.

MISCELLANEOUS.

I've a lecture on the fixed stars, Dr. David Gill, F. R. S., said: "Light takes almost exactly F. R. S., said: "Light takes almost exactly 500 seconds of time to come from the sun; this is a figure easy to remember, and is probably exact to a single unit. The suu is ninetythree millions of miles distant, and this figure I believe to be exact within 200,000 miles. Quite recently the accuracy of these figures has been confirmed in a very remarkable way by different kinds of investigations by different observers, otherwise I should not have quoted them with so much confidence. The parallax of a Centauri is three-quarters of a second of arc; therefore its distance is 275,000 times the distauce of the earth from the sun, and therefore light which travels to the earth from the suu in 500 seconds-i, e., in $8\frac{1}{2}$ minutes—would take 4.36, or a little more than $4\frac{1}{3}$ years to come from a Ceutauri."

DUBENNICK'S process for metalizing wood Cousists in steeping the wood in a caustic alkali for two or three days, according to its degree of permeability, at a temperature between 164 deg. and 197 deg. Fah. The wood is then placed in a second bath of hydrosulphate of calcium, to which is added, after twenty-four or thirty-eight hours, a concentrated solution of sulphur. After forty-eight hours the wood is immersed in a third bath of acetate of lead at a temperature between 95 deg. aud 122 deg. Fah., where it remains from thirty to fifty hours. After a complete drying the wood thus treated is susceptible of a very fine polish, especially if its surface is rubbed with a piece of lead, tin or zinc, and finally finished with a burnisher of glass or porcelain. It then looks like a metallic mirror, and is completely sheltered from all the deteriorating effects of moisture.

Deports from the National Armory at Springfield, Mass., speak well of the new ramrod bayouet. The bayonet portion of the ramrod is 15 inches long, slightly thicker than an ordinary rod, with a four-grooved blunt point. It is held in position when ready for use by a simple spring clasp, invented by Col. Buffington, and when not wanted is pushed down until it occupies the same position as the ordinary Springfield rifle ramrod. On the experimental gun which has recently been fitted up according to Colonel Buffington's plaus, a guarded bead front sight is used, and also a 2,000-yard screw adjustment peep hind sight, with a 1.4 inch windage movement. An automatic allowance for the bullet "drift" is one of the features of the new pattern hind sight.

A PAPER on "The Formatiou of Sugar in the Sugar-cane," was recently read by M. Aime Girard before the Paris Academy of Scieuces. By comparative investigations of the amount of cane sugar and grape sugar in different parts of the sugar-cane in the afternoon and before suurise, the author has found that only in the substance of the leaves does this quantity vary, and that the quantity of cane sugar sinks during the uight to one-half, whilst the quantity of reducing sugar remains almost unaltered. He fluds further that the quantity

of cane sngar in the leaves increases with the illumination, on very bright days reaching nearly one per cent., considerably less on dull ones, and in either case diminishing during the night by one-half. From this the author concludes that the formation of saccharose from glucose takes place entirely in the leaves under the influence of sunlight, and that the saccharose thereupon ascends the cane through the petioles. &c., and collects there.

MPROVEMENTS IN BRONZE AND BRASS ALLOYS. ↓ —A patent has been obtained by Prof. A. K. Huntington for improvements in metallic alloys, the object of which is to secure strength, elasticity, and closeness of grain by the addition of a cheap and easily accessible material. For this purpose, to the copper or alloy he adds a small quantity of silicious iron which may contain a small proportion of other metals, such as manganese, tungsten, or the like. The mixture is made while the materials are in a molten state and as nearly as possible at the same temperature. As examples of alloys made according to the invention, to copper and tin in the usual proportion for gun-metal add not more than 2 per cent. silicious iron; to copper and tin in the usual proportion for brass add not more than 5 per cent. silicious iron; in bronzes or brasses where tin is present besides copper and zinc, a less proportion of silicious iron is used than when there is no tin. Generally, when zinc forms part of the alloy it is preferred to use silicious iron containing a proportion of manganese.

M. DAZARE WEILLER has conducted a series of valuable experiments with the object of ascertaining the relative electric conductivity of metals, submitting the results to the Société Internationale des Electriciens. They are referred to a pure silver wire, 1 millimeter in diameter, and having a resistance of 19.37 ohms per kilometer at 0 deg. C., as a standard. The following are his figures:—Pure silver, standard 100.00; pure copper, 100.00, silicon bronze (telegraph), 98.00; alloy of equal parts silver and copper, 86.65; pure gold, 78.00; pure aluminum, 54.20; silicon bronze (telephone), 39.00; alloy of equal parts silver and gold, 16.10; Swedish iron, 16.00; pure Banca tin, 15.45; 10 per cent. aluminum bronze, 12.60, Siemens steel, 12.00; pure platinum, 10.60; pure lead, 8.88; pure nickel, 7.89; antimony, 3.88.

EDULARD LANDRIN, who had previously shown that when an intimate mixture, in certain proportion, of pure lime and quartz is raised to a white heat, the resulting cement sets slightly on contact with water, but becomes very hard in the presence of carbonic acid, has shown us the results of some new experiments on the hydraulicity of cements that (1) silicates of lime raised to high temperatures set with difficulty, and in any case do not harden in water, according to M. Fremy's experiments; (2) for the calcination of cements to exert a maximum influence on the setting, in connection with water, of the compound obtained, the process must be carried sufficiently far for the

lime to act on the silica so as to transform it into hydraulic silica and not into fused silica: and (3) carbonic acid is an indispensable factor in the setting of siliceous cements, inasmuch as it is this substance which ultimately brings about their hardening.

R. C. V. Boys recently read a paper before the Physical Society on a phenomenon ectro-magnetic induction. Between the of electro-magnetic induction. poles of an electro-magnet a small disc of copper is hung by a bifilar suspension. If the magnetic field is uniform and the disc at an angle to the lines of force, then on making the magnet it is jerked parallel with the lines of force. If it is a changing field, and the disc perpendicular to the lines of force, it is repelled on making the magnet and attracted ou breaking by the nearest pole. This phenomenon, which was observed by Faraday, was shown by Mr. Boys to be useful for determining the intensity of a magnetic field by measuring the throw of the disc on magnetizing and demagnetizing. It might also be employed to measure the resistance of bodies in the form of plates, from their diameter, moment of inertia, and observed throw. Any structural difference of resistance in different directions in the body might be determinded by its means. Mr. Boys illustrated his remarks with curves of results obtained by experiment. Lord Rayleigh considered that the effect of self-induction on the results was not likely to be serious.

A n important piece of work has just been brought to a successful conclusion in Rome, in the complete renewal of the leaden envelope of the dome of St. Peter's Church, in Rome. It has occupied twelve years, and has cost over 200,000 lire (£8,000). The original covering was applied to the dome in an imperfect fashion, which made continuous repairs a necessity; and at last it was determined to strip off the whole envelope and substitute a new one on a better system. New lead was imported from Spain and mixed with the old lead, in the proportion of one part old to two parts new. The total weight of the new cover is given at 354,305 kilogrammes, and if it were spread out flat it would occupy an area of 6,152 square meters, or about an acre and a half. In stripping off the old plates three of them were found to be of gilded copper.

т a recent meeting of the Berlin Physical Society, Professor Lampe spoke on the on the subject of a hypothesis respecting the formation of the solar system set up by M. Fave in place of Laplace's hypothesis. According to M. Faye's theory, in the original uniform nebular mass, vortices were formed which gave rise to the existence, first, of the middle planets, and then, ultimately, of the outer planets. This hypothesis was advanced as an explanation of the fact that the moons of Uranus and Neptune revolved in a direction opposite to that of the sun, the planets, and the other moons, a fact which was not accounted for by Laplace's theory. Only a brief communication, however, had yet been published of M. Faye's hypothesis, which, too, appeared to betray a

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BOILER EXPLOSIONS—THE CAUSE AND THE REMEDY.

BY THOMAS KAYS.

Contributed to Van Nostrand's Engineering Magazine.

uous investigation, the cause of steam quite equal to that of dynamite. boiler explosions has, until recently, remained a profound mystery. The theories of explosions were numerous. The most prevalent were "low water," "hot iron," "high pressure," "mere escape of steam," "superheated steam," "electrical," "gaseous," and the "spheroidal."

The theory most generally accepted was that of low water. This theory was in conflict with facts as established by unquestionable evidence, and therefore

many refused to accept it.

The other theories were alike erroneous, and the result was much confusion of opinion upon the subject. The real cause was discovered by Daniel T. Lawson, of Wellsville, Ohio. He conceived the idea, and has fully demonstrated the fact, that water is an explosive, and that all steam boiler explosions are caused by the explosion of superheated water; reduction of pressure, followed by a sudden check to the exploding water, the result of which is a striking blow far in excess of the tensile strength of boilers.

The Lawson theory, briefly stated, is latent heat, it returns to water.

this:

steam boiler is water, and water, when

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Since the introduction of steam as a der pressure, will explode upon a sudden motive power, and in the face of contin- removal of that pressure, with a force

> The boiling-point of water varies with pressure. In a vacuum, water boils at 70° sensible heat. Under atmospheric pressure it boils at 212°, and cannot be made hotter unless confined under additional pressure, because the escaping steam carries off the heat as fast as fire can impart it. In a steam boiler under 10 lbs. pressure it boils at 241°: 50 lbs., 300° ; 100 lbs., 340° ; 200 lbs., 389° .

Water when heated to the boiling point requires 966° additional heat to change it from the state of water to the state of steam. This change is substantially instantaneous at all pressures. As each molecule of water absorbs the last of the 966° it instantly explodes into As the last degree is absorbed cohesion is overcome and repulsion becomes the predominant power.

The change of steam to water is also that the explosion occurs upon a sudden instantaneous. Steam remains in its new state only so long as it retains the 966° of latent heat, and the moment it is at full volume, with only 212° of sensible heat, parts with one of these degrees of

The explosion of water is similar to The only explosive material about a that of gunpowder, in some respects, but different in others. Each grain of gunsuperheated, which can be done only un-powder passing from the solid to the gasa certain degree of heat. So with water. off to fill the boiler very many times. Each molecule of water, at the instant it has absorbed 966° of heat above the boil- of water is lowered by simply diminishing point, explodes and passes from ing the pressure. They show this, and water into steam. The expansive quality also show the true theory of boiler exof the two is different, powder increasing plosions. They prove in the most conin bulk 800 times, while water increases clusive manner that the sensible heat 1,720 times. The mode of exploding above 70° stored in the water concenand the general result, large and sudden trates in a part of the molecules of water, increase of bulk, are similar. In other giving to them the 966° necessary to respects they differ widely; the explosion change them into steam. of powder is by chemical action, the ex- ceases to boil, no heat is applied, and by plosion of water is by physical change only. merely reducing the pressure the water

able particular. water may explode—one molecule, the the water begins to boil the second half, or the whole mass. These various time. They are already stored up in the amounts in exploding produce results ranging from violent explosions to mild

boiler.

When a grain of powder starts to go from the solid to the gaseous state no It may be confined, power can stop it. but combustion, once begun, goes on to So with a molecule of water. It may be put under such pressure that it will not fully expand, but, enough to convert 921 lbs. of this superonce begun, it changes its state from water to steam.

The true source of the development of the great destructive power in a steam boiler is the sudden concentration of the sensible heat in the water above 212° (or above 70°, in case of a vacuum caused by the condensation of steam) into a part of the 966° necessary to change them from the state of water to the state of

That the stored heat in a boiler concentrates to form steam is shown by familiar experiments.

As, for instance, causing water at less than 212° to boil by placing it in a vacuum; or, by merely condensing the steam overheated water in a bottle.

Again, take a steam boiler under pressure of 100 lbs., and a corresponding temperature of 340°. Remove the fire and the formation of steam will cease. After a short time raise the safety valve, and the water will begin to boil and genthe pressure is reduced, until a tempera-

eous state explodes when it has absorbed steam will be thus generated and blown

These tests show that the boiling point The water Water differs widely from powder and again boils. The 966° above the boiling all other explosives in another remark- point necessary to cause ebullition are Only a portion of the not absorbed from the fire at the instant water.

Take a boiler containing 10,000 lbs. of ruptures and the safe operation of the water at a pressure of 200 lbs. and a corresponding temperature of 389°. Suddenly reduce the pressure to 50 lbs. per square inch, under which pressure water explodes at 300°. There are stored in each of the 10,000 lbs. of water 80° of sensible heat above the exploding point —in the aggregate 800,000 thermal units, heated water into steam. In an instant these 89° of sensible heat in each pound of water are absorbed by the molecules of water at the surface and for a considerable depth, and suddenly these 921 lbs. of superheated water explode into

Thus, it will be seen that there is sufthe molecules of water passing into them ficient destructive power stored in the boiler when thus put in action to cause an explosion. If the reduction of pressure caused by the withdrawal of steam be moderate, and such draught be continuous and uniform, there will be no danger; but if the draught is considerable in quantity and instantly checked, the nascent steam thus suddenly formed and thus suddenly checked will give an impact or striking blow upon the shell of the boiler, the aggregate force of which is equal to the weight of the water before it passed into nascent steam multiplied by the square of the velocity with which it strikes.

The instantaneous check to the exploderate and give off steam continuously as ing water acts upon the boiler with the same effect as that produced by quickly ture of 212° is reached, and enough closing the valve of a watermain. In the one case it is the weight of the falling water, and in the other it is the force of exploding water, but the striking effect of the blows is the same, and is meas-

ured by the same rule.

Take a boiler 48 inches in diameter, 19 feet long, and place in it 10,000 lbs. of water. Then raise the temperature to 400°, and the corresponding pressure will be about 235 lbs. About $\frac{1}{200}$ part of the water, or 50 lbs., passes into steam, occupying the balance of the space of the boiler, about 86 cubic feet. temperature is 188° above 212°. amount of sensible heat, above 212°, stored in the remaining 9,950 lbs. of water is 1,870,600 thermal units, equivalent in mechanical energy to 1,444,103,-200 foot-pounds. Suddenly reduce the pressure from 235 lbs. to normal. At 235 lbs. it required 400° to evaporate water, at normal pressure only 212°—a difference of 188°. There are stored in the boiler 1,870,600 units of sensible heat above 212°, enough to convert about 1,936 lbs. of the remaining water into steam, which would occupy, under 235 lbs pressure, about 3,000 cubic feet of space. Rating the velocity of the nascent steam at one-half the velocity of full steam discharged into the air $(1967 \div 2)$, would give a striking force of over 23,000 lbs. per square inch upon the shell of the boiler.

Again, start with a pressure of 25 lbs. (at which the Westfield exploded in New York City, in 1871), and a corresponding temperature of 269°, and only 57° above 212°, and the amount of sensible heat stored above 212° would be 567,150 thermal units. Reduce the pressure to 0, corresponding to 70°, and the 9,950 lbs. of water would contain 1,980,050 thermal units, sufficient to convert 2,049 lbs. of water into steam. Rating the weight of the water and the velocity of the nascent steam as in the last case, this would give a striking blow of over 24,000 lbs. per square inch.

Take a boiler half full of water, under a pressure of 200 lbs. and at 389°, and suddenly inject into the steam space a quantity of cold water. Condensation is instantaneous. Instantly the superheated water at 389° is in a vacuum ure is superheated, and possesses a highwhere it will explode at 70°. Under ly expansive power. Upon a sudden rethese circumstances a large portion of moval of the pressure, without a corre-

whether one-quarter, one-half, or the whole, the striking force will be sufficient to tear into shreds any boiler ever made.

If the withdrawal of steam is slight, even if followed by a sudden check, no damage ensues with boilers of the usual tensile strength; but if the withdrawal be considerable and the check instantaneous, an explosion follows. With the varying degrees of draught and sudden check come violent explosions and mere rupture.

The distinction between rupturing and exploding is generally overlooked. When a boiler gives way at a weak point, resulting in damage, it is often called an When ruptured by mere explosion. pressure, the force exerted upon the shell being gradual and uniform, the weak point yields while the balance re-Serious damage may remains intact. sult, but a uniform and unobstructed flow of steam never produces the phenomenon properly called an "explosion."

With an explosion the actual destructive force exerted is not measured by the tensile strength of the boiler nor by the regular pressure of the steam. The force is far in excess of either—five, ten, and often twenty times as great, an immense aggregate concussive and destructive force that tears asunder the weak and the strong parts at the same instant and demolishes everything within a large radius.

All writers on steam boiler explosions, in trying to account for their violence, have made the mistake of commencing the calculation at a point of time after the rupture has commenced. The fact is, there is violent internal action at the instant preceding the actual rupture of the boiler, and the rupture is the result of such action Rupture may be caused by the mere pressure of steam, but it is usually caused by an internal concussive force. It is certainly illogical to say that boilers are ruptured or burst by mere pressure while working with a pressure of only one-fifth their actual tensile strength.

The rational solution of a steam boiler

explosion is this:

The water in the boiler under pressthe water will explode into steam, and, sponding reduction of the temperature,

it starts into violent evaporation. This oritices of about two inches in diameter coming in contact with the solid and unyielding shell of the boiler. The result is that the aggregate force of this nascent steam strikes every square inch of the shell of the boiler at the same instant and with the same force, and with a power far in excess of the tensile strength of the boiler; and, moreover, this force is augmented at the instant the shell gives way by an immense reserve power caused by the further evaporation of the water in the boiler.

This theory is in unison with natural laws, and upon it every explosion, bursting or rupture of steam boilers can be fully explained, and cannot be upon any

other.

REMEDY.

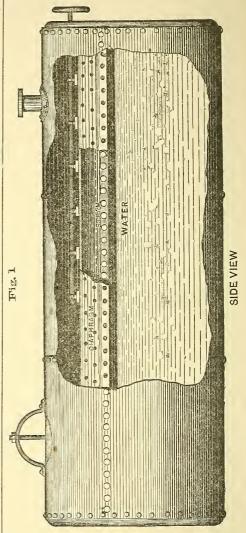
Mr. Lawson, having discovered the cause, naturally turned toward the remedy, which is a simple one, and consists in the construction of a boiler with a partition plate, or diaphragm, dividing it into two compartments, the lower containing the water, and the upper containing steam only. The steam passes from the lower to the upper compartment through numerous small perforations and a number of small valves in the diaphragm. The aggregate openings of the valves and perforations should be less than the valve through which the engine is supplied. By this means the pressure upon the surface of the superheated water is kept approximately uniform, and all sudden explosions of any dangerous quantity of water into steam and consequent striking blows are avoided.

The diaphragm extends the length and width of the boiler, and is firmly riveted to the sides and ends thereof, as shown by figures 1 & 2. It may be circular or flat, and so located as to cut off about two-thirds of the usual steam

space.

The perforations and valves vary with boilers of different size. The aggregate area of all the perforations and valve orifices should be about ten per cent. less than the area of the steam port. In ordinary-sized boilers there should be one perforation of one-quarter of an inch in diameter to each horse-power, rating the diaphragm. ten square feet of heating surface to the horse-power, and such number of valve use such small valves should be closed.

mass of nascent steam is checked by as to make up the balance of the aggregate area.

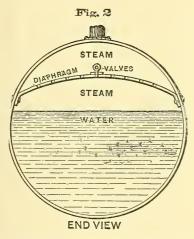


This lessening of the aggregate area ten per cent. below that of the steam port will give a very slight diminution of pressure in the engine with steam working at full stroke, but will practically give full pressure at every other point of cut-off.

There must be two steam gauges used, one connected with the water space below, and one with the steam space above,

When the boiler is set and ready for

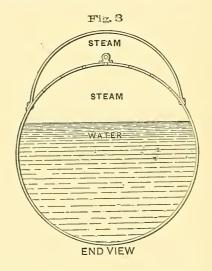
As the steam is generated and the engine put in operation at its full capacity, any additional steam required is obtained by gradually and partially opening such valves until the required amount is liberated and ascertained, when such valves are set, and need but little further attention. In thus arranging such valves particular attention should be paid to the steam gauges. The valves paid to the steam gauges. should be opened only to that extent at which the pressure upon the superheated water in the lower compartment, as shown by the gauges, remains approximately uniform with that in the upper, with the engine in full operation. Thus arranged, any unusual and sudden withdrawal of steam from the upper chamber is attended with no possible danger.



Boilers thus constructed and arranged are protected against explosions, whether the water wholly or partially fills the water compartment. If wholly filled a sudden reduction of pressure in the steam compartment can instantly affect only the surface of the water to the extent of the aggregate area of the perforations and valve orifices, and no dangerous quantity of water can be thus exploded. As the pressure upon the water below the diaphragm is thus slightly reduced, small portions of the water pass into steam and maintain uniformity of pressure.

If the water should get low, thus accumulating an unusual quantity of steam below the diaphragm, there can be no danger of an explosion. The discharge

of steam from the ordinary boiler into the empty pipes and cylinder upon the sudden opening of the valves, is at a velocity of over 100,000 feet per minute, and for an instant there is a great reduction of pressure upon the surface of the superheated water. This cannot occur with the Lawson diaphragm in a With it the passage of steam from the water compartment below the diaphragm to the steam space above it is limited to that quantity used by the engine with the piston moving at the rate of, say, 600 feet per minute, and cannot exceed this precise amount to any great extent, although the steam may, from some unusual cause, be temporarily rushing from the steam space above the diaphragm fifty times as fast. The dia-



phragm limits the quantity of steam discharged from the water compartment to the exact amount necessary, to drive the engine in full operation, and the liberation of this amount at such uniform rate can be attended with no possible danger.

The Lawson diaphragm is to the steam boiler what the air chamber is to the hydraulic ram. It performs a similar, but much more important, function. The elasticity of the air moderates the otherwise solid blows of water upon the pipes; the diaphragm preserves uniformity of pressure upon the water, and thus prevents its explosion and the consequent violent and irresistible concussive blows upon the shell of the boiler.

Explosions are thus prevented, not by extra strong boilers, but by preventing the occurrence of the cause. Boilers thus constructed can be safely operated at a pressure closely approaching their actual tensile strength.

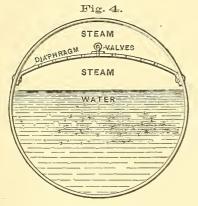
The invention is applicable to every style of boiler, and can be readily applied, internally or externally to new or

old boilers.

Figs. 1 to 7 fully illustrate the inven-Figs. 1 and 2 show an internal, and Figs. 3 to 7 an external application. Fig. 3, moderate pressure; Figs. 1, 2 and 5, high pressure, and Figs. 6 and 7, very high pressure.

Up to June, 1881, no person had ever intentionally exploded a boiler in accordance with any certain theory or plan, or with a knowledge of the true

cause.



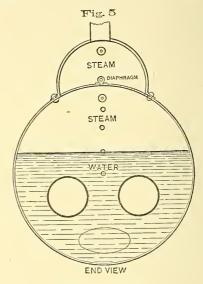
On the 16th of that month Mr. Lawson, at Munhall, near Pittsburgh, Pa., publicly tested his theory, and exploded a boiler of the ordinary style having a tensile strength of 768 lbs., at a pressure of but 290 lbs., being 478 lbs. less than the actual strength of the iron.

The experiment was made by suddenly discharging a considerable quantity of steam at 290 lbs. from the boiler into a closed cylinder, the explosion occurring the instant the cylinder was filled.

In March, 1882, he made further experiments at the same place under the inspection of a commission of U.S. engineers, appointed by the Secretary of the Treasury, and fully tested a boiler with his invention attached.

eter, with only 18 inches of water, run-1the cylinder.

ning down to 11 inches, 4 inches below the fire line, stood every test of rapid escape and sudden check of steam up to a pressure of 300 lbs., without the slightest injury. The same boiler, with the center of the diaphragm removed, reducing it to the ordinary-style boiler, with 22 inches of water, 7 inches above the fire line, was exploded at a pressure of only 235 lbs., 65 lbs. less than the boiler had withstood with Lawson's device, under precisely the same circumstances, except as to the quantity of water.



HIGH PRESSURE.

This discovery and invention remove all obstacles to the use of high pressure.

With immunity against explosion, higher pressure is safely secured, and with it greater power and economy attained.

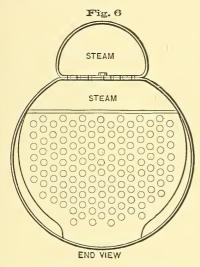
The invention has other advantages of great importance.

DRY STEAM.

It produces dry steam, and prevents "foaming," "priming," or "entrainment."

The cause of these evils is that a large quantity of steam taken suddenly from a boiler at one point greatly reduces the pressure upon the water immediately under the point of exit, while the full pressure of the steam remains upon the surface of the water at every other point, and the re-The boiler having the Lawson dia-sult is that portions of the water are conphragm, and being 30 inches in diam-stantly forced out with the steam into

sudden withdrawal of the steam from the boiler at one point in large quantities, while in direct contact with the surface of the water, decreases the pressure upon the water nearest the point of exit, causing it to rise up in the shape of a cone, while at all other points it is depressed below its former level, and by the sudden withdrawal of the steam in this manner, the pressure upon the water is at every half stroke of the piston reduced below the boiling point of the previous instant. The successive half strokes of the piston are followed by the cut-off of steam, which changes the pressure upon the water. This gives to the water a continual churning motion, the cone-



shaped column of water rising at each many times its own weight. steam, the balance of the water rising and sand, a substance two thousand times its This commo- own weight. falling correspondingly. ure being changed at rapid intervals below the boiling-point of the water of the ward motion. Again, if the motion of to start into violent ebullition.

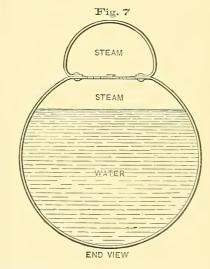
With the diaphragm, the steam passes greater specific gravity, is dropped. from the lower compartment to the upper, not at one point, but in small quan- device the greatest velocity of the steam tities at many points; and the steam is when it passes through the small oriused being taken from the upper com- fices in the diaphragm, and the check partment, all the concussive force and in- comes when it is discharged into the uptermittent pressure and motion are ar-per compartment, and as the motion of rested and confined to the upper com- the steam is checked it drops the sedipartment, and the result is that the ment. Another law is that all sediment pressure upon the surface of the water is settles where there is the least motion.

At each half stroke of the piston the uniform; there is no rising and falling of cone-shaped columns of water, no irregular pressure, no churn-like motion to the water, no irregular and violent ebullition.

Incrustation.

With boilers thus constructed, incrustation is wholly prevented. All foreign solid substances held in suspension or solution are separated from the water and deposited upon the diaphragm, where they do not interfere with the generation of steam and whence they can be readily removed.

This results from natural laws. All matter free to move occupies positions according to its specific gravity. Water in motion has the power of moving solids



Air, in · half stroke and falling at each cut-off of only moderate motion piles up hills of Compressed steam has tion is greatly increased by the press- much greater power than air. The water and steam in a boiler have a rapid upprevious instant, thus causing the water the carrying substance is checked, the foreign matter it is carrying, if of a

In the operation of a boiler with this

stantly going on in this chamber which greatly aids in thus depositing the sediment. It is this, the steam is drawn from have any chance to fasten themselves to this chamber for use. At each cut-off of the shell of the boiler. the supply of steam to the engine there is a slight intermittent motion to the having been solved, and a perfect prethere is a decrease in the specific gravity tainment of dry steam, absence of inof the steam, resulting from the change crustation, and safety with high pressure, of pressure, and this decrease of gravity are we not upon the threshold of a new and intermittent motion all tend to de- era in the use of steam? posit the sediment. This boiler, there-

There is still another operation con- fore, with no other contrivance, thus

Thus, the mystery of boiler explosions steam in this chamber. At each cut-off ventive devised, accompanied by the at-

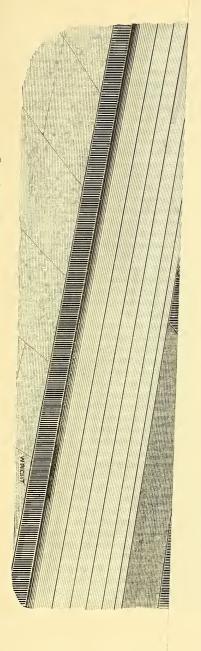
THE TEMPERATURE OF THE SOLAR SURFACE.

By J. ERICSSON.

From "Nature."

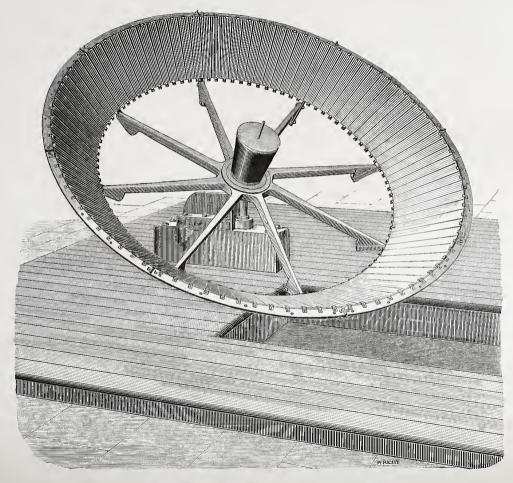
The power developed by the sun motor upon by the reflected radiation in such a recorded in Nature, vol. xxix. p. 217, has manner that each point of its surface reestablished relations between diffusion ceives an equal amount of radiant heat and energy of solar radiation which in a given time. The said reflector is prove that the temperature of the surface contained within two regular polygonal of the sun is extremely high. therefore, during the summer solstice of ninety-six sides, the perimeter of the 1884, carried out an experimental investitheir density diminishes gradually to- tact at the vertices.

I have, planes twelve inches apart, each having gation for the purpose of demonstrating of eight feet diameter, that of the lower the temperature of the solar surface cor- plane being six feet. The corresponding responding with the temperature trans- sides of these planes are connected by mitted to the sun motor. Referring to flat, taper mirrors composed of thin glass the illustrations previously published, it silvered on the outside. When the rewill be seen that the cylindrical heater of flector faces the sun at right angles, each the sun motor, constructed solely for the mirror intercepts a pencil of rays of 32.61 purpose of generating steam or expand-square inches section, hence the entire ing air, is not well adapted for an exact reflecting surface receives the radiant determination of the amount of surface heat of an annular sunbeam of 32.61× exposed to the action of the reflected 96=3130 square inches section. It should solar rays. It will be perceived on in-spection that only part of the bottom of 0.011 less than the total foreshortened the cylindrical heater of the motor is superficies of the ninety-six mirrors if acted upon by the reflected rays, and that sufficiently wide to come in perfect con-Fig. 2 represents a wards the sides of the vessel; also that transverse section of the instrument as it owing to the imperfections of the surface appears when facing the sun; the direct of the reflecting plates the exact course and reflected rays being indicated by of the terminal rays cannot be defined. dotted lines. The reflector and conical Consequently, the most important point heater are sustained by a flat hub and eight in the investigation, namely, the area radial spokes bent upwards towards the acted upon by the reflected radiant heat, ends at an angle of 45°. The hub and cannot be accurately determined. I have spokes are supported by a vertical pivot, accordingly constructed an instrument of by means of which the operator is enlarge dimensions, a polygonal reflector abled to follow the diurnal motion of the (see Fig. 1), composed of a series of in- sun, while a horizontal axle, secured to clined mirrors, and provided with a the upper end of the pivot, and held by central heater of conical form, acted appropriate bearings under the hub, en-



Captain Ericsson's Solar Pyrometer, erected at New York, 1884.

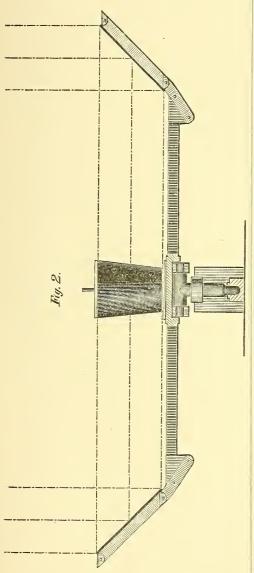




Captain Ericsson's Solar Pyrometer, erected at New York, 1884.



ables him to regulate the inclination to correspond with the altitude of the lumi-The heater is composed of rolled plate iron 0.017 inch thick, and provided with head and bottom formed of nonconducting materials. By means of a screw-plug passing through the bottom



scarcely necessary to state that the pro-solar intensity at 17° 12′ reaches 66.2°

portion of the ends of the conical heater should correspond with the perimeters of the reflector, hence the diameter of the upper end, at the intersection of the polygonal plane, should be to that of the lower end as 8 to 6, in order that every part may be acted upon by reflected rays of equal density. This condition being fulfilled, the temperature communicated will be perfectly uniform. A short tube passes through the upper head of the heater, through which a thermometer is inserted for measuring the internal tem-The stem being somewhat perature. less than the bore of the tube, a small opening is formed by which the necessary equilibrium of pressure will be established with the external atmosphere. It should be mentioned that the indications of the thermometer during the experiment have been remarkably prompt, the bulb being subjected to the joint influence of radiation and convection.

The foregoing particulars, it will be found, furnish all necessary data for determining with absolute precision the diffusion of rays acting on the central vessel of the solar pyrometer. But the determination of temperature which uninterrupted solar radiation is capable of transmitting to the polygonal reflector calls for a correct knowledge of atmospheric absorption: Besides, an accurate estimate of the loss of radiant heat attending the reflection of the rays by the mirrors is indispensable. Let us consider these points separately.

Atmospheric Absorption.—The principal object of conducting the investigation during the summer solstice has been the facilities afforded for determining atmospheric absorption, the sun's zenith distance at noon being only 17° 12' at New York. The retardation of the sun's rays in passing through a clear atmosphere obviously depends on the depth penetrated; hence—neglecting the curvature of the atmospheric limit—the retardation will be as the secants of the zenith distances. Accordingly, an observation of the temperature produced by solar radiation at a zenith distance whose secant is twice that of the secant of 17° 12', viz., and entering the face of the hub the 61° 28', determines the minimum atmosheater may be applied and removed in pheric absorption at New York. The rethe course of five minutes, an important sult of observations conducted during a fact, as will be seen hereafter. It is series of years shows that the maximum

F., while at a zenith distance of 61° 28' it is 52.5° F.; hence, minimum atmospheric absorption at New York, during the summer solstice, is $66.2^{\circ}-52.5^{\circ}=13.7^{\circ}$ F., or $\frac{13.7}{66.2}=0.207$ of the sun's radiant energy where the rays enter the terrestrial atmosphere.

In order to determine the loss of energy attending the reflection of the rays by the diagonal mirrors, I have constructed a special apparatus, which by means of a parallactic mechanism faces the sun at right angles during observations. consists principally of two small mirrors, manufactured of the same materials as the reflector, placed diagonally at right angles to each other; a thermometer being applied between the two whose stem points towards the sun. The direct solar rays entering through perforations of an appropriate shade, and reflected by the inclined mirrors, act simultaneously on opposite sides of the bulb. The mean result of repeated trials, all differing but slightly, show that the energy of the direct solar rays acting on the polygonal reflector is reduced 0.235 before reaching the heater.

In accordance with the previous article, the investigation has been based on the assumption that, the temperatures produced by radiant heat at given distances from its source are inversely as the diffusion of the rays at those distances. In other words, the temperature produced by solar radiation is as the density of the rays.

It will be remembered that Sir Isaac Newton, in estimating the temperature to which the comet of 1680 was subjected when nearest to the sun, based his calculations on the result of his practical observations that the maximum temperature produced by solar radiation was one-third of that of boiling water. Modern research shows that the observer of 1680 underrated solar intensity only 5° for the latitude of London. The distance of the comet from the center of the sun being to the distance of the earth from the same as 6 to 1000, the author density of the rays was as 1000° to $6^{\circ} = 1000^{\circ}$ 28,000 to 1; hence the comet was subjected to a temperature of 28,000 $\times \frac{180^{\circ}}{2}$

times greater than that of red-hot iron" at a temperature of 840°. The distance of the comet from the solar surface being equal to one-third of the sun's radius, it will be seen that, in accordance with the Newtonian doctrine, the temperature to which it was subjected indicated a solar intensity of $4^{\circ}\times1,680,000$

 $\frac{1,000,000}{3^{\circ}} = 2,986,000^{\circ} \text{ F.}$

The writer has established the correctness of the assumption that "the temperature is as the density of the rays," by showing practically that the diminution of solar temperature (for corresponding zenith distances) when the earth is in aphelion corresponds with the increased diffusion of the rays consequent on increased distance from the sun. This practical demonstration, however, has been questioned on the insufficient ground that "the eccentricity of the earth's orbit is too small and the temperature produced by solar radiation too low" to furnish a safe basis for computations of solar temperature.

In order to meet the objection that the diffusion of the rays in aphelion do not differ sufficiently, the solar pyrometer has been so arranged that the density, i. e., the diffusion of the reflected rays, can be changed from a ratio of 1 in 5,040, to that of 1 in 10,241. This has been effected by employing heaters respectively 10 inches and 20 inches in di-With reference to the "low" ameter. solar temperature pointed out, it will be perceived that the adopted expedient of increasing the density of the rays without raising the temperature by converging radiation, removes the objection urged.

Agreeably to the dimensions already specified, the area of the 10-inch heater acted upon by the reflected solar rays is 331.65 square inches, the area of the 20-inch heater being 673.9 square inches. The section of the annular sunbeam whose direct rays act upon the polygonal reflector is 3,130 square inches, as before stated.

from the same as 6 to 1000, the author of the "Principia" asserted that the density of the rays was as 1000° to $6^{\circ}=28,000$ to 1; hence the comet was subjected to a temperature of $28,000 \times \frac{180^{\circ}}{3}$ the same as 218.1° to 1, while the reflector of

the solar pyrometer intercepts a sunbeam of 3,130 square inches section, it follows that the reflector will receive the radiant

heat developed by $\frac{3,130}{218.1^2}$ = 0.0658 square

inch of the solar surface. Hence, as the 10-inch heater presents an area of 331.65 square inches, we establish the fact that the reflected solar rays, acting on the same, are diffused in the ratio of 331.65

to 0.0658, or $\frac{331.65}{0.0658} = 5{,}040$ to 1; the

diffusion of the rays acting on the 20inch heater being as 673.9 to 0.0658, or 673.9

 $\frac{0.0658}{0.0658} = 10,241 \text{ to } 1.$

The atmospheric conditions having proved unfavorable during the investigation, maximum solar temperature was not recorded. Accordingly, the heaters of the solar pyrometer did not reach maximum temperature, the highest indication by the thermometer of the small heater being 336°.5, that of the large one being 200°.5 above the surrounding air. No compensation will, however, be introduced on account of deficient solar heat, the intention being to base the computation of solar temperature solely on the result of observations conducted at New York during the summer solstice of 1884. It will be noticed that the temperature of the large heater is proportionally higher than that of the small heater, a fact showing that the latter, owing to its higher temperature, loses more heat by radiation and convection than the former. Besides, the rate of cooling of heated bodies increases more rapidly than the augmentation of temperature.

The loss occasioned by the imperfect reflection of the mirrors, as before stated, is 0.235 of the energy transmitted by the by our investigation is requisite to predirect solar rays acting on the polygonal vent undue density of the solar atmosreflector, hence the temperature which phere. the solar rays are capable of imparting to fully ten-thousandfold) must be regarded surface does not reach 3,000° C.

as an actual temperature, since a perfectly transparent atmosphere, and a reflector capable of transmitting the whole energy of the sun's rays to the heater,

would produce the same.

The result of the experimental investigation carried out during the summer solstice of 1884 may be thus briefly stated. The diffusion of the solar rays acting on the 20-inch heater being in the ratio of 1 to 10,241, the temperature of the solar surface cannot be less than $298.87^{\circ} \times 10,241 = 3,060,727^{\circ} \text{ F}.$ underrated computation must be accepted unless it can be shown that the temperature produced by radiant heat is not inversely as the diffusion of the rays. Physicists who question the existence of such high solar temperature should bear in mind that in consequence of the great attraction of the solar mass, hydrogen on the sun's surface raised to a temperature of 4,000° C., will be nearly twice as heavy as hydrogen on the surface of the earth at ordinary atmospheric temperatures; and that, owing to the immense depth of the solar atmosphere, its density would be so enormous at the stated low temperature that the observed rapid movements within the solar envelope could not possibly take place. It scarcely needs demonstration to prove that extreme tenuity can alone account for the extraordinary velocities recorded by observers of solar phenomena. But extreme tenuity is incompatible with low temperature and the pressure produced by an atmospheric column probably exceeding 50,000 miles in height subjected to the sun's powerful attraction, diminished only one-fourth at the stated eleva-These facts warrant the conclution. sion that the high temperature established

It is not intended at present to discuss the large heater will be $200.5^{\circ} \times 1.235 =$ the necessity of tenuity with reference to 247.617°; but the energy of the solar the functions of the sun as a radiator: rays acting on the reflector is reduced yet it will be proper to observe that on 0.207 by atmospheric absorption, conse-merely dynamical grounds the enormous quently the ultimate temperature which density of the solar envelope which the sun's radiant energy is capable of would result from low temperature, preimparting to the heater is $1.207 \times |$ sents an unanswerable objection to the 247.617°=298.87° F. It is hardly neces- assumption of Pouillet, Vicaire Saintesary to observe that this temperature Claire Deville, and other eminent sav-(developed by solar radiation diffused ants, that the temperature of the solar

ON THE MECHANICAL EXAMINATION AND TESTING OF PORTLAND CEMENT.

BY HENRY FAIJA, Assoc. M. Inst. C. E.

From Selected Papers of the Institution of Civil Engineers.

It may be assumed that the object of testing cement is to ascertain its value for constructive purposes, and it is the aim of the author to examine the tests to which cement is generally subjected, and to see how far they attain their ob-

iect.

The requirements of any test or combination of tests are, that the conclusion shall be absolute, and that the time occupied in arriving at that conclusion shall be as short as possible; and further, as all opinions formed by the examination of a cement must be based on the results of previous examinations and tests, it is evidently of importance that a uniform means of testing should be adopted, so that users and manufacturers may be able to compare their own tests with those by other people. At present the tests made by one person are of little use to anyone else, owing to differences of manipulation and detail.

The ordinary practice is to find the value of a cement by making it into briquettes and ascertaining their tensile strength when seven days old, as well as by its fineness, weight, and color; from the results obtained and their relative bearing to each other, a correct opinion is

presumably arrived at.

Mr. Mann lately presented to the Institution the results of some experiments on the adhesion of cement to different materials, and by this means ascertained its value for constructive purposes. Nor must it be forgotten that Mr. Grant has introduced the sand test into this country from Germany, which is another test for adhesion; for although the briquettes made of cement and sand are tested for tensile strength, it is the adhesion between the sand and the cement which gives the briquette its tensile strength. Whether either of these enables a more definite conclusion to be arrived at than the ordinary method, the author does not venture to offer an opinion. He thinks, however, that neither of them is likely to

supersede the generally accepted requirements of a test, and that therefore they are detrimental to the interests of uni-

form testing.

The author in this paper first considers the details of manipulation and other matters affecting the results obtained in a cement test, and afterwards the properties which a good cement should show in each detail.

In testing cement for tensile strength several points materially affect the result; namely, the percentage of water used in gauging. The skill of the manipulator, which practically means the time occupied in reducing the cement to a proper consistency, and the dexterity in filling the moulds, so that a sound briquette free from air bubbles may be obtained with the minimum of water in the minimum of time. The form and construction of the mould in which to form the The careful removal of the briquette. briquette from the mould and its subsequent handling. The time which elapses between the formation of the briquette and placing it in water. And the manner and speed at which the weight is put on the briquette when being tested.

It may be assumed that, as far as the tensile strength is concerned, a better result than can possibly be secured in practice should be obtained in the testing room; but it is of greater importance that a uniform result should be obtained by all persons engaged in testing cement, and that a uniform procedure should be adopted, than that the acme of perfection should be attained. The skill of the operator having a great deal to do with the result, it is necessary to reduce the operation of gauging the cement to, as nearly as possible, a purely mechanical process. This can be accomplished by a gauging machine devised by the author. It gives in ordinary hands as good a result as the most expert operator obtains when gauging in the usual way with the trowel. By employing the gauger the cement is

is necessary is obviated.

The advantage gained by adding the minimum of water for gauging has for sometime been acknowledged, and the re-Proceedings of this and other Institu- four hours. tions, are sufficient to show that such is quantity, as hardly any two cements require the same, and it can only be determined by making experimental pats previous to proceeding with the test. The maximum amount of water may, however, be fixed at 18 per cent.

That the time occupied in gauging a sample of cement effects the result obtained is hardly a matter to prove by ex- it is fixed to most of Mr. Adie's testing periment, it being evident that if cement machines. It ensures the weight being is worked after it has commenced to set, its nature must be altered, and the result cannot be reliable; this, though it applies in a more marked degree to quick-setting

cements, it is true of all.

The form of briquette must materially affect the result in testing for tensile strength. The author can only say that the form brought forward three years ago by Mr. Grant in a paper before this Institution, gives undoubtedly the best results, and he should like to see that form universally adopted. It is hardly necessary to add that the moulds should be of metal; resting on glass, metal or other nonporous bed. If a porous or partially porous bed is used, an excess of water in gauging is quickly withdrawn from the briquette, and the setting being thus accelerated, a better result is shown at short dates, though eventually there would probably be no difference. But inasmuch as a test of cement for practical purposes never exceeds twenty-eight days, and is generally confined to seven, a misleading ing considered the limits which it was result is obtained if this detail be not attended to.

allowed to elapse between the gauging ing the different results to be expected of the cement and placing the briquette from applying the weight at different in water. Experiments prove that the speeds. Though an experiment comprisgreatest tensile strength is obtained when ing only six hundred examples cannot

brought to a proper consistency to be the briquette is put in water directly it put into the moulds in considerably less is set. With quick setting cements this time; and by reducing the labor and may be in an hour or two after gauging, wrist work necessary to properly gauge a and with slow-setting cements it may be cement, the inducement to slovenly man-extended to ten, fourteen, or twenty ipulation and the use of more water than hours. The danger, however, is, that if this practice be adopted, in unskillful hands the briquette may be put in water a little to soon, when the cement would be acted upon detrimentally. It is theresults of experiments by Mr. Grant and fore advisable that a given number of others, and by the author, which have hours should be determined upon, and from time to time been published in the this by practice has been fixed at twenty-

In testing all other materials the rate the fact. It is impossible to name a fixed of speed at which the weight or strain is applied is considered, but it seems to have been persistently ignored when testing cement. Its importance, however, must be as great with one material as with another. Mr. W. Matthews, M. Inst. C.E., and Mr. P. Adie, Assoc. Inst. C.E., have devised an automatic arrangement for running the weight along a steelyard, and put on to the briquette at an even and regular speed, though no special speed seems to have been adopted. The principle on which it works is that of a falling weight governed by a water-brake. Dr. Michaelis' machine, in which the weight is applied by allowing shot to fall into a pan at the end of a compound lever, as well as Bailey's machine, in which water is used instead of shot, might both be easily arranged to apply the weight at a standard speed.

Notwithstanding the different results which it is evident would be obtained through variation in the speed of applying the weight, the author is not aware of any exhaustive experiments having been made, or any conclusion arrived at on the subject; he has therefore recorded the details of an experiment comprising over six hundred briquettes. quettes were broken at five different speeds, varying from 100 lbs. in one second to 100 lbs. in two minutes; these bepossible to adopt in practice. By taking the average percentage of difference he The next item of importance is the time has been enabled to draw a curve, showperhaps be considered conclusive, yet it enables a fairly good average to be obtained, especially as several different cements were used throughout the experiment. Although in each series the same cement was used, the gauging was all done at one time, and in exactly the same manner, by the same man.

The results were as follow:

Increase per cent. between 100 lbs.
in 1 min. and 100 lbs. in 2 mins.,
Increase per cent. between 100 lbs.
in 30 sees. and 100 lbs. in 1 min.,
3.528

Increase per cent. between 100 lbs. in 15 secs. and 100 lbs. in 30 secs., 4.028

Increase per cent. between 100 lbs. in 1 see. and 100 lbs. in 15 secs., 10.726

Total per cent. between 100 lbs.

in 2 mins. and 100 lbs. in 1 see., 23.142

The great difference shown by this experiment must impress every user and manufacturer of cement with the importance of adopting a standard speed at which the weight is to be applied; and it seems that the most convenient would be either the 100 lbs. in fifteen seconds, which the author uses in his testing room, or a little slower, but certainly not slower than 100 lbs. in thirty seconds, on account of the length of time which a test would occupy.

The author is of opinion that by adopting the before-mentioned or similar means and appliances for gauging the cement and priming the briquettes, the results obtained by different experimenters would approach more nearly to each other, a better estimation of the value of a cement would be possible, and a comparison would be more easily and more definitely

decided.

The determination of the fineness of a cement can of necessity only be carried out in one manner, and is not subject to error. The weight per striked bushel, however, is open to considerable argument. The manner in which the measure is filled is of necessity all-important, it being assumed that the cement is to be put into the measure as lightly as possible.

As an alternative test or in conjunction with the foregoing, the specific gravity of a cement may be ascertained, with this advantage, that while the weight per bushel varies with the fineness to which the cement is ground, the specific gravity is of necessity constant.

The usual method of determining whether or not a cement will blow, is by making a few small pats and placing them in water as soon as they are set, which may be in one hour or two or more hours, according to whether the cement is quick or slow-setting, and by examining them daily to see if they develop cracks or otherwise alter in form. That the inference drawn from the result thus obtained is a true one, is extremely doubtful; and the author has thefore adopted another method to determine what, in his opinion, is the most dangerous property that a cement

can possess.

Some years ago the author made numerous experiments with the view of accelerating the setting or hardening of cement and concrete, which resulted in his taking out a patent for that purpose. The process is only referred to because out of it has come a little apparatus of great value in the testing room, which enables a decided opinion to be formed within twenty-four hours as to whether the cement under examination will blow, or if it is a safe cement to use. The principle of the author's process for hardening is to subject the concrete immediately on gauging to a moist heat of about 90° Fahrenheit, and afterwards to keep it in a warm silicious bath at a temperature of about 100°. It was found that if by accident these temperatures were materially increased, the concrete sometimes gave all the appearance of having been made with a blowy cement. From this it was opined that a good cement would not blow at these temperatures, and further experiments have proved such to be the case, and also that a cement which does not stand this treatment is improperly made and will sooner or later blow. The author therefore devised an apparatus. It is a moist heat chamber and bath conbined in a small space; but the bath is only water instead of silicious. The mode of using it is to make a small pat of the cement under examination on a piece of glass and immediately to place it into the moist heat part of the apparatus. When it is set, which, even in the case of very slow-setting cements, will be within two or three hours, it is taken out of the moist heat chamber and placed in the bath. If next morning the pat is perfectly sound, it is decided that the cement will not blow; if, on the other hand, it is swollen and

fair to say that because under these conditions the pat was blown, it is an improperly made cement, for the blowing might be due to extreme freshness,

Under these circumstances, therefore, it is necessary to put a small quantity of cement on a tray in a thin layer, and to let it thoroughly cool for two or three days. If a pat made from this cooled cement blows when submitted to the influence of the moist heat and warm bath, the author would on no account advise the use of the cement. On the other hand, if it does not blow, it is pretty clearly shown that the cement is sound but too fresh, and that the bulk should be turned over three or four times and cooled before use.

The author proposes in the second portion of the paper to consider the properties which a good and useful cement should develop when being tested, under three divisions; firstly, those properties which have already been amply experimented upon, and which may be considered as proved and acknowledged; secondly, those which may be termed the problematical, which though inherent to a good cement may also be found in a bad one; and thirdly, the absolute strength and behavior of the cement at different dates.

Of the first, it may be considered that both users and manufacturers are cognizant of the importance of a cement being finely ground, and that, given a certain cement, the best result is obtained when it is finely ground. There is, however, a limit which commercially cannot be exceeded, except of course at an increased price, or until other machinery has been invented for grinding. This limit seems to be that the cement shall all pass through a sieve having 900 meshes to the square inch, and shall not leave more than 10 per cent. residue on a sieve having 2,500 meshes to the square inch. This degree of fineness is for all practical purposes sufficient; and if a user thinks he can obtain a better result by having a finer ground cement, he should be prepared to pay a higher price for it.

blown, then the cement is considered un- with a proper quantity of lime in its comfit for use. It would not, however, be position and well calcined, and a light cement the reverse; but it does not of necessity follow that such is the case. It is also possible to have a cement too heavy, and, as pointed out by the author ten years ago, and by others since, the weight must bear a definite relation to the fineness. Of necessity the finer the cement, the lighter it will weigh. It is generally considered that a cement of the fineness previously specified should weigh from 110 to 114 lbs. per striked bushel, when the bushel measure is filled in a manner similar to that adopted by the author. The specific gravity corresponding to this weight and fineness is from 3.00 to

> The color of a cement is almost too problematical to deserve consideration, except when examining cements made from similar materials, as the varying properties of different raw materials must of necessity affect the color. But the author puts very little value on these problematical tests as a means of assisting in the determination of the value of a cement.

> The absolute behavior of the cement when made into briquettes and tested at different dates, and the careful examination of its behavior during gauging and setting, are the best means for determining its value for constructive purposes.

The determination of what the tensile strength of a cement should be at certain dates, is the one point on which all authorities seem to differ, and yet it is the one test which has been experimented upon more than all other tests put together. If, however, all the experiments which have been published are examined, it does not seem difficult to arrive at a just conclusion. The author has made thousands of tests in this direction; he has examined all the tests which have been published in England, and some of those from Germany, and the result of these tests and examinations is, that good cement, which practically continues to increase in strength for a period over which it is possible to make a test, has a tensile strength, when tested in the ordinary manner, of not more than 300 lbs. or 350 The weight per striked bushel specific lbs. per square inch at the expiration of gravity or density of a cement, are in the seven days from gauging; while the same highest degree problematical tests. It is examination shows that many of those ceassumed that a heavy cement means one ments which at the same age carry 400 lbs. or 500 lbs. actually deteriorate before

they are a year old.

The author is of the opinion that the strength at a single date does not define with sufficient accuracy the value of a cement; but that two dates should be determined upon, and the increase per cent. in strength between those dates will better define the nature of the cement than the actual strength at either. As an example, the two following cements may be cited:-

_	3 Days.	7 Days.	28 Days.	3 Months.
No. 1	390	460	520	510
No. 2	205	375	490	590

Consider the behavior of No. 1 cement up to twenty-eight days. It is superior in every way to No. 2; though the increase of strength between each date is but little, while No. 2 increased 85 per cent. between the three and seven days, and 30 per cent. between the seven and twenty-eight days. The latter therefore appears, as indeed is proved by the result of a three-months' test, to be still increasing in strength, and likely to do so for some time, while No. 1 is a cement which develops all its strength in a short period. It is therefore not likely to increase in strength with age, and may possibly deteriorate. It would not, however, satisfy the case to define only the increase per cent. which should take place between certain dates; but a minimum and maximum strength should be determined upon at the earlier date, as indicative of a good cement, and a specified increase above that for all future tests named. In the author's opinion, the tensile-strength of a briquette three days old should be at least 175 lbs., and should not exceed 275 lbs. per square inch; the increase of strength between the three days and seven days should be from 40 to 50 per cent.; and if a twenty-eight days' test is adopted, the increase should be from 20 to 30 per cent. of the strength shown at the seven days.

A slow-setting cement does not practically increase in temperature during setting; it is only the quick-setting ones

crease in temperature as much as 16° and 18° Fahrenheit in eight or ten minutes from gauging, and will not return to their normal temperature for more than an hour. If cement possessing this characteristic be cooled, it will be slower setting, and the increase in temperature during setting will not be so great. This test may therefore be often useful in assisting in the immediate determination of the value of a cement.

The author maintains that there should be a uniform standard specification, compliance with which would ensure a thoroughly good and sound cement, which manufacturers would be able and willing to supply at the ordinary market prices. A standard specification has been for many years adopted in Germany and other countries, and has proved of great benefit to the industry, and there is no reason why it should not be equally beneficial in this country. Shippers, and users who require only a few hundred tons at a time (and it must not be forgotten that these take up the bulk of the cement made in this country), know that they were obtaining a good and useful article. Such an arrangement would in no way interfere with engineers, or others who use large quantities, adopting their own specification, and there is no doubt manufacturers would be prepared to comply with their demands under special conditions. order, however, to ensure success, a standard specification should be one which, while meeting all requirements, should be simple and conclusive, and at the same time expeditious. In nine specifications out of ten, many of the items demanded are contradictory, and many often use-It therefore seems necessary to examine the clauses usually inserted in a specification, and see what assistance they render in determining the value of the cement, so that the actual clauses in a specification may be reduced to a minimum. Taking them in order, they generally appear to be: first, the weight; second, the fineness; third, the examination. of pats; fourth, the color; fifth the tensile strength at seven days; sixth, that the cement shall set in a certain time.

Notwithstanding that this hitherto has been considered a good and efficient test, the author believes no correct estimate which develop this characteristic. Many of the value of the cement can be arrived quick-setting cements when fresh will in- at by the comparison of the results obtained, and therefore would substitute and the increase per cent. between those for them the following:—

First, fineness; second, absence of blowing, determined by the use of the apparatus already described; third, the tensile strength at three and seven days, such a long period.

dates. In addition, a twenty-eight days' test might be adopted if practicable; but in many cases—certainly in all cases of shipment—it is impossible to allow the examination of the cement to extend over

TEMPERATURE OF THE SUN.

BY DEVOLSON WOOD, M. A., C. E.

Written for Van Nostrand's Engineering Magazine.

This most important point in Mr. F. Gilman's criticism, in the last September proved that the same law of gravitation number of this magazine, of my article in the last July number, is whether the law of the inverse squares as applied to heat is applicable to extended surfaces. If his assertions be taken in place of proof, little need be said; but on this point there is a show of reasoning, inasmuch as he asserts that "gravitation, light and radiant heat conform to the same law." In examining the truth of this assertion, we begin with the fundamental principle of the attraction of matter—that the attractive force between any two particles varies directly as the products of their masses and inversely as the square of the distance between them; thus expressed The law has no existence in refer-7°2 . ence to a single material particle only, as

Gilman seems to imply. Do light and Mr. radiant heat necessitate two bodies, one to impart and the other to receive? But the law especially referred to is that of the inverse squares. Can it be said of gravity that the force varies inversely as the square of the distance unless there be an external body, so that there may be mutual action between them? Is it necessary to have an external object in order that the intensity of heat shall vary inversely as the square of the distance? (Admitting the law, for the moment). In the case of gravitation, is not the attractive pull (so to speak) the same on both bodies, regardless of their relative size? The answers to these questions are evident, and are only made to show fundamental differences.

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Mr. Gilman says: "But it has been prevails in a spherical homogeneous mass of any dimension, when the distance is measured from the center "-a statement partly true and partly false. He here confines his attention to one body, and in that sense it is not correct. In the next place, assuming that he would have the action of the sphere upon a particle, it is not true if the particle be within the sphere, for in that case it is found that the attraction upon the particle at the center of the sphere is zero, and increases as the distance from the center to the surface. Is this true of a hot sphere? Is it true that there is no heat at the center of such a sphere? And does the heat increase from the center outward? Answers are unnecessary. But for fear that it may be said that this is not a fair case, it will be well to observe that this law of increase of gravity in the homogeneous sphere is deduced from the fundamental law of gravity between particles.

But it may be properly claimed to be true for the attraction of a homogeneous sphere upon an external particle—or, to be more precise, for the attraction between such a sphere and an external particle. But it must be observed that this "has been proved" by means of the law relating to the attraction between particles; and in this proof it is assumed that the attraction between the external particle and the most remote one of the sphere is precisely the same as if they And is this the same with light and heat? were the only particles considered. In other words, the attraction is the same whether bodies intervene or not. Has it been proved that the same law holds for

radiant heat in this case? The above result may be thus stated: The attraction between two homogeneous spheres is the same as if their entire masses were concentrated at their respective centers. Can a similar statement be made of radiant heat? If so, where is the proof? Further, by means of the fundamental principle above stated, the principle holds for gravity when the spheres are not homogeneous, provided only that each of the concentric spherical shells of which the spheres may be conceived as composed, are of the same density, but varying from one to the other in any manner. When Prof. Tait is correctly reported, it will be found that he does not support the theory that the law of the inverse squares "is also applicable in the case of heat radiating from a spherical body, such as the sun." We do not understand how Mr. Gilman can insist upon this law of the inverse squares in this case and at the same time admit that the law of Petit and Dulong is reliable even to nearly 400° F., since the latter is entirely at variance with the former. I suppose that both of us have typographical errors in the notation of the formula

 $Q = 1.146 fa^t$.

In my article it should have read a = ture!

1.0077, and Q should be substituted for r, and with these corrections the formula was sufficiently correct for my purpose, though not exact; but if the formula quoted by Mr. Gilman gives better results, or results more favorable to Captain Ericsson's theory, we are willing he should profit by it. It is safer to extend an approximate empirical formula beyond the limits of strict applicability, than to use a principle not founded on reason or experiment. We made no claim for accuracy of the result, but simply showed that, according to recognized theories, the temperature of the sun might be about 5000° Fahr.

But Mr. Gilman asserts that the law of the inverse squares "gives the temperature of the medium in the vicinity of the body" and "Capt. Ericsson has proved the temperature of the medium in the vicinity of the sun is at least 1,303,640° Fahr." What medium is here referred to? Is it the luminiferous ether? If so, who can say that it is not diathermanous? Or is some other medium referred to? The assertion is a bold one.

Finally, let Mr. Gilman extend his calculation, by assuming that the body is 400,000, 100,000, &c. miles from the center of the sun and determine its tempera-

GERMAN REGULATIONS AS TO THE CONSTRUCTION OF IRON BRIDGES.

From "The Engineer."

regulations for the delivery of iron structures for bridges and buildings was discussed. The subject was then referred to the Saxony Association, for the drawing up of a series of regulations on the been under consideration, and during last autumn the work projected was accomplished.

struction has been treated in a compre- of foot passengers and carriages.

At a meeting of the German Associa- hensive manner; less attention having tion of Architects and Engineers held in apparently been given to that portion of October, 1881, the question of normal the subject which refers to building work. The following is a summary of the principal features of the scheme in question, given in detail by the Wochenblatt fur Architekten und Ingenieure.

I. Technical basis of construction: (A) subject. The matter has since that time Intrinsic weight of the structure; (B) Alterable vertical load.—(a) In railway bridges this is represented by a train consisting of three of the heaviest loco-In the scheme drawn up—signed by motives in prospective use, and an un-Messrs. Centner, Ehrhardt, Frankel, and limited number of loaded goods trucks. Fritzche—the question of bridge con- (b) The traffic on road bridges consists main girders of bridges, of about 651 ft. span, concentrated loads upon one or two axles are more unfavorable than the burden of a crowd, but in the larger bridges the latter is the most unfavorable. This last-named pressure can as a rule be estimated at about 82 lbs. per square foot, but in cases of a compact crowd the pressure may be as high as 114 lbs. per square foot. The prospective burden of carriages has to be estimated according to the probable character of the vehicles and the description of roadway; the portion of the roadway not covered with vehicles being supposed to be filled with a crowd. In some cases regard must be paid to a probable load of street locomotives. (c) In buildings the movable burden of the floors, burden of snow on the roof and wind pressure. (C) Horizontal forces. -(a) The wind pressure acting horizontally may be estimated for the loaded bridge at $30\frac{3}{4}$ lbs. per square foot, and for the unloaded bridge at 51½ lbs. per square foot, or, in a specially exposed situation, even at $57\frac{1}{4}$ lbs. per square foot. (b) In curved railway bridges the effect of the centrifugal force for the maximum speed of the trains has to be taken into consideration. (D) Allowable requirements of the material used in the construction.—The employment of the formulas founded on Wöhler's tests is suggested, but the following strengths are mentioned as maximum requirements: Welded iron, 7,625 tons per square inch; steel, 11.5 tons per square inch. Wide flanged welded iron I girders—where the width of the flanges exceeds that of the German normal profile—even if they have only to support a fixed load, should not be required to stand a test of above 5 tons per square inch in tension. In calculations affecting rivets there should not be more strength claimed than about 3.75 tons per square inch of rivet section. Cast iron should be required to stand tests for extension of 1.625 tons per square inch, and for pressure of 4.75 tons per square inch.

II. Preparations of contract drawings and calculations.—III. The preparation of working drawings.—The drawings and calculations on which a contract is iron, tests can hardly be specified on acbased are, as a rule, prepared by the count of the insufficiency of experience building authorities, and when the ad- relating to them. The cast iron portions judication takes place the contractor re- must be cleanly made of grey soft iron in

apart from the general plan—on the scale of one-twenty-fifth to one-twentieth of the natural size for entire main girders, and one-tenth the natural size for the details, no further working drawings are required. Any defects arising in the work are not to be excused on the ground of want of clearness or imperfections in the draw-Any changes suggested by the contractor are to be notified within a given period. When special working drawings are to be prepared by the contractor, they are to be submitted in duplicate to the building authorities within a given time after the adjudication. Any purchases of materials or other steps taken before the approval of these working drawings are at the contractor's risk. The calculations as to weight are in most cases prepared by the authorities and annexed to the contract. If they are in accordance with the dimensions shown in the drawings no further calculations of weight are required, but the contractor is bound to examine them. Should approximate weights only have been given, the contractor is bound to send in within a given time in duplicate an exact calculation of weights. The following standards of weight are to be taken as a basis:-Cast iron, 452\frac{3}{8} lbs. per cubic foot; wrought iron, 4861 lbs. per cubic foot; steel and ingot iron, 4905 lbs. per cubic

IV. Selection, quality, and testing of the materials.—(a) The bearing portions of the structure, such as the main girders, cross girders, and intermediate girders, as well as all portions which are liable to deflection, are in general to be made of wrought iron. It is recommended in bridge building to use wrought iron instead of cast iron columns. As to the use of mild steels, caution is advised in the present conditions of methods of manufacture. (b) The definition of the quality of the material of the construction must be governed by its working capabilities. (c) The wrought iron used must at least possess the qualities specified in the conditions of classification issued in May, 1881, by the Association of German Ironworks. As to mild steel and ingot ceives attested copies. If these are—the prescribed dimensions. They must

contain neither blisters, holes, fissures, strength must be—against tension 7 tons from lead. per square inch; compression 38 tons minimum thickness of metal for cast iron

columns is \frac{2}{5} inch.

—plates, bars, &c.—the rust and hammer slag are to be removed from the iron, ing together of separate pieces. The mode of cleaning is left to the conof what it is, and is responsible in the instance of chemical cleaning for any subsequent rusting arising from want of care in the removal of the acids used. The cleaned portions are to be coated with a varnish of boiling hot linseed oil, which must be thin and quick in drying. must be properly sheltered. The building authorities are at liberty to arrange for a provisional acceptance when the riveting is completed, after which the grounding of the parts may be effected with a protecting ground paint. For this purpose a varnish of linseed oil with red lead is recommended, but the operation must not take place during damp weather in the open air. This provisional acceptance is not any agreement on the part of the building authorities as to the correctness of the measurements or the number of pieces in the construction. The larger portions are only to be grounded on the building site after revision. After the iron portions are in position, all the joints are to be carefully filled up, at the surfaces of contact, with a putty composed of white lead and linseed oil varnish, and a grounding of red lead is to be applied to the heads of the rivets driven in on the building site. Besides, all spaces between portions of the construction where water might accumulate have to be carefully filled up with asphalt. The entire construction subsequently receives from the building authorities a second coat of ing—of any portions be prescribed, it the factory, provisional screw bolts must should be effected by a strictly uniform coating. is incorrectly called galvanizing in this the factory is recommended.

country, becoming detached. The coatnor any other defects. The minimum ing of zinc must be as free as possible

VI. The manufacture and putting toper square inch. Cast iron columns and gether of the separate parts.—All the supports are tested up to double the burparts of the construction must exactly den for which they are constructed. The correspond with the drawings and fulfill the following conditions:—(a) The portions fastened with rivets or screws must V. Cleaning and painting.—Previous fit closely together. (b) All iron portions to the separate parts being put together must be rolled or forged out of one piece of iron, and not be formed by the weldexceptions have to be specified. tractor's option, but he must give notice Angles and bending are to be avoided as far as possible. (d) The rivet holes must correspond as to diameter and position with the drawings. The holes which are drilled at the building site should be about 1/25 of an inch narrower than the diameter of the rivet requires, so that a good fit is insured after its being en-Until dried, the portions thus coated larged. (e) All screw holes and rivet holes are to be carefully drilled. Where several holes meet each other in the parts to be united, a horizontal dislocation of not more than 5 per cent. of the diameter of the hole is allowable. holes must, however, be made perfectly equal with the rimer, and not by filing on one side. Rivet bolts of proportionately large size must be used in holes thus enlarged. (g) The rivets are to be inserted at a bright-red heat-after being carefully freed from scales—into the duly cleared rivet holes in such a manner that they are quite firm after the head is completed. (h) After the riveting, it is to be tested whether the rivets are quite firm. All that are not firm or do not correspond with the above-named conditions are to be removed and replaced by others. further driving is under any circumstances to be permitted in the cold state. In the putting together of the parts, care is to be taken that none of them is forced into a one-sided tension. Should any portions become distorted in the riveting, the connections must be loosed and the faults carefully remedied.

VII. Extent of completion in the workoil paint. Should the zincing—galvaniz- shops.—In all parts not to be riveted in be inserted. Riveting upon the building The portions thus treated site is to be confined to the smallest posshould be capable of being bent until sible extent, and, therefore, the complethey break without the zincing, i.e., what tion of all possible parts of the work at

VIII. Suspension of the execution and acceptance of the work in the workshop. The building authorities have the right of constant or occasional skilled supervision of work in the workshops, and the necessary appliances and force for tests and examinations must be furnished to them, or obtained by them at the contractor's expense. All portions not according to the prescribed regulations, or otherwise unserviceable, are to be marked in such a manner that their subsequent employment in the structure may be recognized. The examination of the iron material and the control of the execution in the workshop does not prevent the rejection of the work delivered, during or after the erection of the structure, if defects show themselves.

IX. The mode of ascertaining the weight.—For the purpose of computation all parts of the structure should, if possiticable, a certain number of objects seunder it, can be at once rejected.

is liable for any ultimate difficulties. The work. contractor is specially bound to carry out

building authorities, who likewise provide the necessary materials.

XI. The erection on the site.—The methods to be employed in the erection of the ironwork and of the scaffolding are generally left to the judgment of the contractor, but the building authorities have the right in letting out the contract to stipulate for a certain mode of erection. The machinery for hoisting and other appliances have to be supplied by the contractor at his own expense. As the erection of scaffolding, &c., is subject to local regulations, the building authorities are to give the contractor, in the conditions for delivery, all available information, plans, &c., bearing on this point, as also upon the question of land and water transport for materials, &c. Plans of the scaffolding—scale 1:100—are to be submitted within a given time after the adjudication—by the building authorble, be weighed, but when this is impraciple to the local officials for examination and approval. Those parts of the malected by the building committee should sonry on which the bed-plates are to be be officially weighed for the purpose of placed should be put at the disposal of obtaining reliable indications regarding the contractor a given time before the the total weight of the structure. The date fixed for the completion of the ironcomputation then takes place according work. Should the masonry not be ready, to the agreed prices on the basis of the the contractor must be apprised of the total weight as ascertained, if the latter altered circumstances, but any compensadoes not exceed the original computed tion under this head must be a stipulation weight by more than 3 per cent. If the of the contract. The officials charged excess of weight is more than 3 per cent., with the supervision of the erection are the contractor is only paid for 3 per cent. authorized to satisfy themselves in any extra. Any shortness in weight is de- way they wish as to the quality of bindducted. Portions of a structure which ing materials not yet tested. A repetition are more than 5 per cent. above the esti- of tests for strength already carried out mated weight, or more than 2 per cent. in the workshops can only be ordered by the building authorities in special cases. X. The stonework of bridges.—The The contractor is bound to follow the bed stones are delivered to the contractor instructions of these officials within three in the correct position of altitude, and days, but has the right of appeal to the the middle line of the bridge construc- building committee. In urgent cases the tion is marked on the pillars in a distinct officials have the right to order the sus-The contractor is supposed to pension of the work, but if it is found on ascertain by his own measurements, be-appeal to the building authorities that fore the erection begins, the exact dimen- such a course was not justified. the consions, and to control the same according tractor is entitled to compensation for to the drawings, reporting any differences any injury he has sustained, and the peto the building authorities, and awaiting riod of suspension is added to the time their decision; otherwise the contractor originally fixed for the execution of the

XII. The testing and acceptance of the correct and exact placing in position the completed work: (a) super-elevation of the main girders. The masons' and of girders.—Truss and lattice girders, stone-dressers' work in connection with &c., are laid with a camber, which is comthe final works is looked after by the puted upon the principle that after the

work is finished and the load has produced its natural effect, there should remain a camber equaling half the bending which would have been produced by

a similar moving load.

(b) Tests for load.—These vary according to the purposes of the structure. Railway bridges are tested by a train being placed on each of the lines. This train consists of three of the heaviest goods engines available, the first with the chimney in front and the two others with the chimneys in opposite direction to each other, and loaded goods trucks of the heaviest description in use upon the railway in question. These trains are placed upon that portion of the bridge which corresponds with the greatest momentum, and the amount of deflection after six hours is measured in the center of the main girders and at the main piers. The train is then removed and the amount of permanent deflection of the girders is ascertained. Finally the bridge is crossed line, and the amount of transitory and permanent deflection is ascertained. For brought upon the roadway and the footcases the transitory and permanent de- is a suitable period.

flection of the main girders is ascertained, as previously explained. The marching of men in time, as well as the rapid driving of vehicles over the bridge, are not excluded, but must be provided for in the conditions for the construction. The most unfavorable combination of the burdens of the separate openings is produced with continuous girders. A small permanent deflection after the removal of the first trial load cannot be attributed to any defect in the construction if no permanent deformation of the separate parts of the work can be proved. Further trials should, however, not produce any further deflection. The measured elastic deflection with fixed and moving loads must not in any case exceed the computation by 15 per cent. Any differences in temperature which may have intervened should be regarded in such tests. All defects which are rendered visible by the tests, and which can be traced to faulty execution or to the materials used, are to at the maximum speed allowed upon the be remedied by the contractor within a period fixed by the building authorities. The tests for burden are carried out at testing road bridges a testing weight is the expense of the building authorities. The examination of the work with a view paths, where it is left for twenty-four to its acceptance as a whole should take A row of the heaviest loaded place within a given period of its complevehicles which have been provided for in tion. The contractor remains answerable the construction of the bridge is driven for a certain period as to the normal constep by step over it, and is then allowed dition and the good and proper execution to rest half an hour upon it. In both of the work. It is suggested that a year

ON WATER SUPPLY.

Papers read before the Conference of the Society of Arts on the Water Supply held at the International Health Exhibition in July.

From the "Journal of the Society of Arts."

I.

WATER SUPPLY IN ITS INFLUENCE ON THE DISTRIBUTION OF THE POPULATION.

BY W. G. TOPLEY, F.G.S., ASSOC. INST. C.E.

One of the most essential conditions for the comfort and well-being of a population is water, and a little consideration will show that the early settlements of a people have been where, and only where, water occurs.

In a broad and general sense, this fact is patent to all—the banks of rivers and

wide areas of waterless districts are unpeopled; but the fact is equally true in a very limited and restricted sense, not at first so obvious.

The source of all water is the rain which falls on the land; this acts in two different ways, according to the nature of the soil on which it falls. If the soil is porous, or pervious to water, a certain portion of the rain sinks in; if the soil is impervious, the whole of the water either drains off the land into brooks, or passes streams are usually well populated—the back by evaporation into the air. The

water which soaks into a porous soil or rock, accumulates there until it flows out again as springs, or is artificially tapped, and drawn away by means of wells.

Springs occur near where a pervious bed overlies or underlies an impervious bed, or where a valley reaches down to the level at which the rock is saturated with water. In the case of valleys cutting deeply into the rock, the valleys themselves determine the level of satura-

A soil which allows water to sink into it is a dry soil, and is, therefore, suited for habitation and for agriculture. Hence the main conditions which favor the settlement of a district are found in the same soil, or along the outcrop of the same bed. We thus see that geological structure controls the distribution of the population; not only in such great features of the earth's surface as mountainchains, plains, and valleys, but also in the minor divisions of the district.

The outcrop of a narrow band of porous rock, between wide beds of clay, is strongly marked by the occurrence of a long line of villages, each of which obtains its water from shallow wells or springs. The cornbrash, between the Oxford clay and the great oolite clays, is an excellent example of this. So, too, is the markstone in nearly all cases, either (a) obtained rock-bed, between the upper and lower lias. Even a thin and comparatively unimportant bed of sand, ironstone, or limestone, if it only affords a small space fit for arable culture, will be marked by a line of villages. A thin bed of ironstone in the lower lias of Lincolnshire is a good example of this.

When rocks rise from beneath a covering of clay there are often springs at the

junction.

The base of the chalk escarpment, with the line of outcrop of the adjacent upper green sand gives another good example. Here the villages always lie thickly along a definite line. There is a well-marked and constant relation between the outcrop of porous strata and the parish or township boundaries, the longer axes of the parishes crossing the outcrops more or less at right angles. A careful study of the distribution of the villages, and of the relation of their parish boundaries to the main physical features, throws were dependent entirely upon these much light upon the past history of the springs and wells, the houses were concountry, and often enables us to deter-fined to the gravel; when a general sys-

mine the relative ages of the settlements. This branch of the subject does not now concern us; we need only note that the arrangement of the parish boundaries depends upon the sites of the settlements, and that these are controlled by the outcrops of water-bearing beds.

The early settlements in England were nearly always controlled by such circumstances as have been here referred to; but the later development of special towns and districts has depended upon a variety of circumstances. In early times it was around some shrine of special fame or sanctity, or under the shadow of the castle of some powerful noble, that the population clustered and the town increased. A little later it was also in places especially well suited for various manufactures. Within the last 200 years the great development of our mineral wealth (especially of coal and iron) has entirely transformed the country. Large towns have sprung up over the coal-fields, often on wide tracts of clay, where few settlements would otherwise have taken place. The natural surface water supply of such places is often bad and small, and the mining operations frequently drain even this.

The water supply of modern towns is, from a neighboring river, (b) brought from a distance, or (c) obtained from deep wells beneath the town. It thus, except in the first case, differs from that of the original settlement, which always obtained its water from streams, springs, or shallow wells. In far too many cases the primitive source of supply has been continued in use long after the time when it should have been abandoned; and the local source of water supply, essential to the early development of a town, has become a source of danger as the population has increased.

Of the points just mentioned, London affords an excellent example. The old parts of London and its suburbs are built upon gravel resting on London clay. Where small valleys (such as the Fleet) cut through the gravel, there are natural springs; but everywhere water can be obtained in shallow wells sunk through the gravel. So long as the inhabitants tem of water supply was introduced, the population extended over the intervening area of clay. Meanwhile, the increasing population, without any adequate system of drainage, fouled the shallow wells, and rendered them all more or less impure. It is only within the last few years that some of these have been closed by author-

Below the superficial deposit of gravel, there are other sources of water supply for London. The strata beneath lie in a basin-shaped form, and thus favor the accumulation of water. Underneath the London clay there are the lower tertiary sands, holding water which rises in the wells when these are sunk through the clay. Still lower, there is the great mass of chalk in which there is an enormous store of water. Still lower, and separated from the chalk by a bed of clay (gault), is the lower greensand. This, on the south side of London, may yet yield some water, but it can never be the great source of supply which was once hoped

There are, then, with the river, four different sources of water supply at or beneath London, each giving a different quality of water. Probably no large city in Europe is better situated than London for supplying itself with water from within its own area; but so vast has London now become, that all these taken together are insufficient, or inefficient.

others of the great capitals of Europe are built on "basins" like that of London, and hence are able to obtain deep well-water from beneath. Paris, Berlin, and Vienna are good examples. This is a circumstance that could not have been known to the early settlers, who concerned themselves only with the surface sources of water supply.

THE ORIGIN OF WATER SUPPLY.

BY G. J. SYMONS, F. R. S.

This title might possibly be supposed to imply a history of the past, but in this Health Exhibition, pace Old London, we deal chiefly with the present and with the future.

I know no better word than origin wherewith to describe the small portion of the great subject of water supply which I am permitted to discuss.

All water supply comes from the clouds, and it is with the products of the clouds as rain (including therein snow

and hail) that I have to deal.

Perhaps, before describing the general features of rainfall distribution, it may be permissible to explain (for the use of those who have never done it) how the fall of rain is measured. If we imagine a flat dish—a tea-tray, for instance placed upon a lawn during rain, it is obvious that (subject to loss by splashing) that tray would, at the end of the shower, be covered by a layer of water of a depth approximately equal to that which fell upon all portions of the lawn, and the depth of water on it (say $\frac{1}{2}$ inch) would be the depth of the rain fallen. Obviously, besides the loss by splashing, the water on this tray would soon evaporate and be lost, besides which the depth could not easily be accurately measured. For these reasons, some form of funnel is always used, so that the rain may be, as it were, trapped, prevented from splashing out, and from evaporating. In the gauge before you (a very inexpensive one) all known sources of error are guarded against, and, as the water collected by a 5-in. funnel is measured in a jar only $1\frac{1}{2}$ inches in diameter, it will at once be seen that its vertical depth is multiplied nearly tenfold, and, therefore, even one-hundredth of an inch is easily measured.

There are other patterns specially adapted for observation on mountain tops, where they can only be visited once a month; others for observations during heavy thunderstorms, so as to obtain data needful for drainage questions; others in which every shower that falls writes down its history, the instant of its commencement, its intensity during every minute, and the time of its termination; but I must not stand between you and other papers with a discourse on the many interesting points which these gauges bring out.

During the last 25 years I have done what I could towards establishing a complete system of recording the rainfall in this country. In early days the British Association for the Advancement of Science gave considerable help, but some ten years since they dropped it. Government have never given any help at all, and now the whole cost, or 99 per cent.

verified.

Hitherto I have been so overworked, drew many years ago, and which was in- 100 years? serted in the sixth report of the Rivers country.

to single stations the differences are, of ing pipes to the sources whence they at the Stye, in Cumberland, was 190.28 reservoirs of gravitation waterworks; inches, and at Clacton-on-Sea, in Essex, sometimes they pass, as in the chalk disit was only 18.71 inches; that is to say, tricts, for miles beneath impervious strata,

other.

tion as to public policy. There is often the ground; and sometimes they pass a great outcry if the water of one dis- even deeper, as in the red sandstone suptrict is taken to another. there is no relation whatever be- Liverpool and other towns. tween the density of population and the quantity of rainfall, one early is sometimes utilized by throwing a bank that all parts are amply supplied with reservoir behind it, as, for instance in the chief necessary of life. Englishmen the new supply for Liverpool from the have a dread of centralization, but in Vyrnwy, where the reservoir will form a many ways they pay a long price for lake larger than many of those in Cumtheir dread. At present it is not often berland. Sometimes the lakes themselves that any town can even state before Par- are utilized as reservoirs, as, for instance, liament its views as to the effect upon it Loch Katrine and the surrounding lakes, of what its next neighbor may be ob- and sometimes, as at York and London, taining powers to do. Having suggested the rivers are drawn from by powerful one semi-legal question, I may as well pumping machinery. mention at once another. Up to the It is often said that there are few present time, there being no Hydraulic-things so uncertain as the rain. That is office (as I hold that there should be) in both true and false. True as regards

of it, is borne by the observers them- this country, all the larger water quesselves, a body which has now grown to tions come before Parliament as private the very large number of nearly 3,000. I bills, and, provided that they get through do not know the precise number, but committee, they, as a matter of course, there are every year new stations begin- become law-law for all time to come. ning, old ones stopping, and others in- No one can foresee what will be the toterrupted; yet, for 1883, I have just had tal population of this country a century the pleasure of printing perfect records hence. No one can tell where the bulk from 2,433 stations, every record having of the people will reside, nor what will been previously carefully examined and be the need for water in various parts of the country. Water-rights are already very valuable, and they will probably beand my staff has been so small, that the come still more so. Would it be possible discussion of the data falls behind the to safeguard our successors by insisting collection; for this reason I cannot lay that special water-rights, if now asked to before you such data as I wish. How- be created, shall be subject to revision, ever, the map on the wall is the one I without compensation, after the lapse of

However, to return to rainfall, and ex-Pollution Commission. It is not perfect, plain why I stated it to be the origin of but as it is tinted with increasing dark-ness for places with heavy annual falls of must be disposed of, either by evaporarain, it will at least show you the broad tion, percolation, or flow into streams features of the distribution over the and rivers. The first class, evaporation, is, of course, not a supply, and therefore I refrain from going into the subject we must not pursue it. Percolation is in detail, desiring chiefly that you should the source of all springs and of all wellrealize the fact that large tracts of water. Sometimes, as at Lancaster, the country have twice and even three times springs are so large that even a consideras much rain as others. If we descend able town can be supplied by merely laycourse, greater, e. g., in 1883, the rainfall burst forth; sometimes they run into the the one was more than ten times the finally being either pumped up from wells, or even, in rare cases, rising as Here I should like to interpose a questrue artesian wells above the surface of Surely, while plies pumped from extreme depths for

of a Government is to see arcoss a stream, and thereby forming a

our ignorance of the future, false as regards our knowledge of the limits within which the quantity of rain will be found

rainfalls in this country of thirty or more years each, and in a very large majority of them it will be found that the following proportions will be within 7 per cent. of the truth:

the average.

Driest year, 33 per cent. less than the average.

Driest two consecutive years, 26 per cent. less than the average.

Driest three consecutive years, 21 per

cent. less than the average.

There are many other facts respecting the laws of rainfall distribution, concerning which time prevents my saying anything, but I trust that enough has been said to establish the necessity of a perfect system of rainfall registration as the basis of any efficient hydraulic organization.

WATER SUPPLY TO VILLAGES AND RURAL DISTRICTS.

BY EARDLEY BAILEY-DENTON, C.E., B.A., OXON.

village communities and rural districts.

rural districts, in relation to water—the policy of their colleagues. first essential of healthy life—is a posipears to me, should be specially directed man with a capability and courage to exforce.

If it should be understood, too, that the existence of this condition of things is to be traced, not so much to the absence of potable water, or the difficulty There are now hundreds of records of of bringing it into use, as to the disinclination of local authorities to develop the capabilities at their command.

It may be said with truth that, as a general rule, Local Boards and Boards of the truth:

Wettest year, 45 per cent. more than districts, who have been called into existence to supply the sanitary requirements of those districts, are animated with less desire to perform the duties devolving upon them than to avoid them. It is, indeed, notorious that the majority of members of Local Boards are elected under a pledge to oppose such works as sewage and water supply, on the ground that the rates will be increased, and knowing this to be the case, and that few persons of superior position are willing to take part in Local Boards, because they would invariably be outvoted, it is easy to understand why rural districts should be the last to move in the water question. It is, however, very difficult to explain why the clergyman and medical man of rural parishes, whose higher education should be a guarantee that the right thing would be done, fail to exercise proper influence. I believe that I am uttering a fact chance, they are elected to serve on Local which no one can discredit when I state Boards it almost invariably follows that that there is no object in social economy the one forgets what he has said in the which is more important, having regard pulpit as to the influence on the future to the aggregate number of persons af- of sudden death; whilst the other ignores fected by it, than the supply of water to the advice he has given his patients in their sick-chamber in relation to the fatal At the present moment, when the In- effects of inhaling and imbibing those ternational Health Exhibition may help germs of disease which float in foul air to draw attention to sanitary objects of and impure water. Directly they are varying degrees of importance, it may be easy in their chairs as members they conwell to make clear that the condition of tent themselves with the luissez faire

These influences explain how it is that tive disgrace to a country represented by local authorities abstain from appointing a State Department whose efforts, it ap- as surveyor, or sanitary inspector, any to the protection of small communities pose local defects and requirements, and less able to help themselves than large why, when a medical officer does his duty ones; and is a sad reflection on the pres- in explaining the defective character of ent advanced stage of sanitary knowledge the water supply of any portion of his —an admission which the special meteor- district, some reason is soon found for ological condition of the present season, relieving him of his duties, and for apand a possibility of a visit of cholera, pointing another in his stead, the actual brings home to all minds with increased result of all this being that the governing bodies of rural and small urban

districts exercise their functions, when occurred during the last seven years, vice and opinion of men technically qualified to guide them, but by the exercise of their own judgment. You may often whole, a considerable balance to carry over. This advantage, coupled with the frequent and heavy thunderstorms which cellent tradesmen in their respective vo- two, will go far to prevent the scarcity cations—directing the sinking of wells in of water which would otherwise have ocvillage streets in close proximity to leaky curred during the coming autumn; sewers, ditches or cesspools, by which though, unfortunately, this national adthe water intended for the supply of the vantage will be a poor compensation to poorer inhabitants soon becomes foul the agricultural interest, which has sufand unsuitable for domestic use. So fered so severely from the excessive wetgeneral, indeed, has been this abuse, ness of the last few years. that it is no exaggeration to state that Without taking into consideration on

water supply were substituted.

January and February. amount of rainfall in those months of the ta of varying thickness. last winter did not reach two-thirds of From the first source it requires comverely felt at the present time, and would have affected our subterranean supplies fices; in others, where the depth exmuch more than it is now likely to do, ceeds thirty feet, additional power is balanced by the excesses of rain which more powerful pumping, and may involve

compelled to act, not by taking the ad- from 1876 to 1883, which gave us, on the observe a small publican or a grocer—ex- have occurred within the last month or

nineteen out of twenty existing village the present occasion the use of rain wells are quite unfit for their purpose, water, which, under careful management, and that if samples were honestly taken may be collected from roofs and other and submitted to a competent analyst impervious surfaces, and stored in tanks, they would be condemned. Yet they are and which will always form a valuable permitted to exist, and nothing is said means of supply to private dwellings, about them, because the populations in- and in special instances may be made terested are comparatively small, the available even for villages, our rural supdeath rate is not excessive, the dwellings ply, now so often derived from dirty are low in value, and, above all, because ditches and shallow wells, more or less the rates would be increased if a proper polluted by foul matters, may, in the absence of springs, rivulets and impounded I have been induced to offer some re- upland surface waters, be obtained from marks upon the present occasion, not be- subterranean sources of "wholesome" cause I have anything especially new to character. These are to be found in valay before you, but because the facts I rious beds or outcrops of a water rehave just referred to on the constitution taining character, which gather water at of local authorities and the performance a comparatively shallow depth below the of their duties, have been made more surface, such as the post-tertiary beds of pertinent by the circumstance that, at a Norfolk and Suffolk, and the different time when there exists the apprehension drift beds covering the London clay; of a visit of cholera, a scarcity of water the Bagshot sands, the green sand overmay occur, owing to a remarkably dry lying the wealdon and gault clays, the winter being followed by an unusually surface sands and beds of the wealdon hot summer, which the recent thunder- formation, the calcarious grit and coral storms may not sufficiently counteract. rag outcropping between the Kimmer-It is unnecessary to explain that the idge and Oxford clays, and other beds of summer supply of water is very greatly like nature; or from the well-defined dependent upon the fall of rain during water-bearing strata of the chalk, the the preceding winter, i. e., upon the rain onlite, and the red sandstone formations falling in the non-evaporating and dormant months of November, December, it is often found necessary to pass through The mean superincumbent impervious beds or stra-

the average quantity due to the same paratively little motive power to raise months for the preceding 60 years. This the supply to the height required; in deficit would have been much more selfact, in many cases, the application of the had it not been in some measure counter-called for. The second source requires the use of several pumps working in unison. All this has been said and explained before. My desire now is, if possible, through the influence of this meeting, to impress upon Local Boards and Boards of Guardians in rural districts, where, in order to obtain unexceptional potable water, they are obliged to seek it beneath the surface, that the experience already gained in tubular wells goes far to prove that, in the majority of instances the "tubular" system may, with good effect, take the place of the old and more expensive practice of sinking large wells involving brickwork, steining and staging. Economy, important though it be, is however secondary to the more important fact that a tubular well signifies continuous and watertight piping from the surface of the ground to the subterranean water level beneath, so that the entrance of polluted surface or subsoil water (as is so frequently the case in ordinary shaft wells) is rendered impossible. In addition to this advantage it should be pointed from the tubes, and they are kept clear out that tubular wells are very rapidly by an arrangement adopted by Messrs. made, and can be readily removed should Legrand and Sutcliff, of Bunhill Row, or quality. Moreover, the whole of the of water. This is effected by suddenly materials employed may be applied, when liberating a column of water after it has withdrawn, to the same purpose in an- been raised to a sufficient height above other place.

few disadvantages attending the adoption probably be two, and in one of 1,000 of tube wells which it is right at once to people probably five. From figures refer to. One is, that if, owing to acci-kindly given to me by the patentees it whereas in ordinary shaft wells, there cost of fixing them. in combination.

tubular wells already mentioned, i. e., where it can be readily obtained.

those that can be worked by ordinary lift and atmospheric pumps at a depth of less than 30 feet from the surface, and those that raise water by more powerful machinery from deep subterranean waterlevels, the modus operandi and cost will be as follows:—

In the first instance, taking, as examples, cases where the populations may severally be 400 and 1,000, and where there exists a constant supply of water at 20 feet below the surface, recourse may be had to Norton's Abyssinian tube wells. The water is reached by driving tubes down through the ground to the water level. The first tube is pointed and perforated for a few inches with holes varying in size from $\frac{1}{8}$ to $\frac{1}{4}$ inch. after length of tubing is driven into the earth at the selected site, and each succeeding length is connected with the last by a screw joint. The perforations at the base are four times as much as is necessary to obtain the full flow of water it occur that the water found or sought has not answered expectations in quantity matter that may obstruct a free influx its normal level. The number of tube I may here state that there are some wells required in a village of 400 would dent, pumping is stayed, there will be no would appear that the capital expended supply during such time, and if it should in providing the wells and appliances will happen that the stored supply should not exceed 2s per head of the population. run out before the pumping is resumed, Of course this only refers to the provimuch inconvenience may be experienced; sion of the tubes, the pumps, and the There are many being room for more than one pump, instances of small villages and hamlets such an objection may be obviated. An- where one well and pump alone would other disadvantage is that should the suffice; but there are others besides those demand for water increase beyond the given as illustrations, where a number of capability of supply the only remedy is these wells may be necessary, and which to sink others, and to utilize two or more should be united by means of a cast iron horizontal main or mains, with intervals To render the nature and cost of tububetween the vertical pipes, governed by lar wells, which necessarily vary in charthen nature of the water-bearing seam out acter and size according to local circum- of which the water supply is obtained. stances, as intelligible as it is possible to make them to rural sanitary authorities, The motive power to work the pumps I may shortly state that, adopting for may vary in kind; water-power may be illustration, the two characters of the used when it is close at hand, or gas

In the second instance (deep sources), the tube wells consist of iron piping wick, a siphon arrangement has been fixed in bore holes, which latter, in fact, form the well, with the piping to serve as I belong, when devising the water supply the pump barrel and rising main, to raise the water into a service reservoir. These bore holes will vary in depth according to local features, and in diameter from 5 to 15 inches, according to the quantities 6,000, which we had intended to obtain of water to be raised. The core of pipes from a direct adit driven into the bed of form as already intimated, a continuous tube from the surface of the bore hole to between Boars Hill and Abingdon; but the water level below, and are made perfeetly flush both inside and out, and must gestion from Mr. J. Thornhill Harrison, be watertight. They are sunk for a sufficient depth below the standing water an inquiry held by him, pointed out that level as to secure an effective discharge, the water bed which we were making The pump is fixed within the tubing, preparations to tap might be considered which forms a cylinder, and is connected a natural reservoir, from which the rewith the engine on the surface by rods quired supply could be raised by means properly guided within the tube. Special of a siphon passing over the bank impains are taken so to construct and fix pounding the water. This object was to the surface, repaired, and replaced, of discharging 330 gallons a minute, laid For the first 15 or 20 feet of the well a from a reservoir holding 125,000 gallons shaft 5 or 6 feet in diameter is necessary, (which it was found necessary to make in which to fix the necessary gearing con- within the calcareous grit for storage and necting the engine with the pump, and ready discharge), the bottom of which to place the air vessel, &c., regulating was 40 feet higher than the highest part the lifted supply to the reservoir. It of Abingdon. The shorter leg of the would appear from figures supplied me siphon is about 9 feet in length, and the primary outlay varies from £500 in a way out of the calcareous grit into the case where the lift is 100 feet, the supply reservoir, rises above the crown of the 40 gallons per minute, the depth of the siphon (which it generally does during to £750, where the lift is upwards of 250 independently of the siphon; but when feet, the supply 50 gallons per minute, it sinks below that level, then the siphon the depth of the bore-hole over 300 feet, action is called into play. This arrangeand its size 9 inches.

larly into subterranean water, supplies culty of any kind. may not infrequently be obtained by the use of siphons for drawing water out of C. E., adopted a somewhat similar conwater-yielding basins, to which there is trivance, whereby he effected a very great no natural outlet, by deflected pipes laid saving in the cost of the works. over or through the rims of the basins. now been in operation for more than The extraction of the required supply is eight years, and is stated by Mr. Pritcheffected by dipping the shorter leg of the ard to work satisfactorily. siphon into the water bed forming a whilst working automatically, involve ready-made reservoir, and carrying the very little outlay in maintenance, and larger leg into the village requiring the they would be adopted much more fresupply, to act, with proper appliances, as quently than they are at present, if their a service main. This automatic mode of special nature and advantages were more raising and delivering water has already fully understood. They have been used been found available for towns as well as with great advantage for the drainage villages.

In the cases of Abingdon and Warfound very beneficial. The firm to which for the former town (under the immediate supervision of Mr. C. F. Gower), adopted this expedient for raising the necessary supply for a population of over 6,000, which we had intended to obtain coral rag, or calcareous grit, outcropping which we abandoned in favor of a sugof the Local Government Board, who, at the pump that it may be readily brought effected by means of a 9 in. pipe capable Messrs. Tilley, of Walbrook, for reaches very nearly to the bottom of the works which we have now in hand, that reservoir. When the water, finding its bore hole 300 feet, and its size 7 inches, the night), the discharge is by gravitation ment has been in existence at Abingdon Besides tubular wells sunk perpendicu- for four years, without any hitch or diffi-

> At Warwick, Mr. Edward Pritchard, of land, and for the lowering of water

standing in bogs. I may mention, as an illustration, that in Scotland the Earl of Stair drained by this means a wet marsh near Culhorn-house, which had rendered that residence unhealthy. The siphonpipe (seven inches in diameter) was half a mile long, and it has drawn down the water nine feet.

There is yet another means of obtaining water for villages, which it would be wrong to exclude from the consideration of sanitary authorities, as in some instances, we know from experience already gained, that it can be resorted to with advantage; I refer to the use of waters from cultivated surfaces, which the Rivers Pollution Commissioners have designated "suspicious" waters. To raise them above suspicion they should be collected and filtered through a bed of natural soil, extending to about one pole (of superficial area) per head of population. By this means the water would be made very superior to that consumed by the majority of householders in rural districts. The preparation of filter-beds of natural soil is simple enough. A plot of land, as porous and free in its subsoil as can be obtained, should be selected, and made suitable by special treatment, at such an elevation relatively to the land from which the water would be obtained, and lected. to the village which it is intended to the former on its surface, and allow it, after it has passed through the filter, to collect in a storage reservoir, and thence to reach the village at a serviceable The filter itself should be deep- used. height. ly underdrained, and the water to be filtered through it evenly distributed over its surface. No manure whatever should be applied in it.

The water of underdrainage, when found to contain ingredients of an objectionable character, which the analyses of Professor Way have shown may be the case, can be rendered perfectly unobjectionable by a second filtration through a plot of prepared soil, rigidly preserved

from the application of manure.

When we are taught by chemists to believe that the extraordinary purifying powers of aerated soil will render innocuous the discharged sewage of towns in which exists organic nitrogen in con-

ral soil, the water of underdrainage, already once filtered, may be freed from any putrescible ingredients it may have once contained.

This expedient is only suggested where a village being in the neighborhood of an estate which the owner has underdrained, such owner will allow the water to be diverted from a natural stream, and filtered before it is supplied for domestic use.

I will close this short paper by drawing the attention of sanitary authorities in rural districts to the "Reservoirs Act, 1877," by which powers are given to the owners of land to supply water "to any sanitary or other local authority" by contract, and to charge their estates with the outlay on works.

WATER SUPPLY.

BY EDWARD EASTON, M. INST. C. E.

The object of this paper is to put before the conference, in as concise a form as possible, the considerations which should govern the supply of water for domestic and other purposes, not with the intention of enunciating any new thing, but with the hope of drawing attention to well-recognized principleswhich are too often forgotten or neg,

The three chief points which have to serve, as will receive the off-flow from be considered in relation to this subject

1. The source of the water.

2. Its distribution.

3. The conditions under which it is

1. With regard to the source, it is evident that, in designing a waterworks, the engineer has to provide that the water shall be adapted to the purposes for which it is intended, to be used, both as

regards quality and quantity.

The question of quality will depend upon circumstances. It is essential, of course, that in every case the water shall be free from contamination by organic and other impurities; but the necessity of its being chemically free from other constituents will depend, to some extent, upon the purpose for which it will be used; for instance, in a manufacturing district, where the water is required for dyeing and such-like purposes, it siderable amount, we must be satisfied must be free from certain mineral inthat, by a second passage through natu-gredients, whereas for the supply of

drinking water and for general purposes, this is a qualification which need not be insisted on.

It is now generally admitted that a soft water is preferable to a hard water, provided that the storage and distribution are properly carried out, and in every case where there is a choice of supplies, that which is soft, or which can be softened by simple means, should sumer. be chosen.

Clark for softening hard water by the deposition of a portion of the line, is of a very simple character, and it has been successfully adopted in many cases.

Sources of water, proper for use, may be classed under two distinct heads. 1st. Those which are afforded by nature in a state absolutely pure and fit for use, such as water drawn from wells and deep-seated springs. 2d. Those derived from water-courses or gathering grounds which are open to the atmosphere, and which must necessarily be exposed to the risk of contamination from external agen-

In the case of the former, no works for storage or purification are necessary, the stratum of rock or other material from which the water springs, forming a natural reservoir and filter.

In the second case, it is necessary (a) that all direct pollutions shall be prevented from coming into the source; and (b) that in almost every instance, efficient means of filtration should be provided. The filtration ought, wherever it is found impossible to altogether prevent the chance of contamination, to include the use of some deodorizing agent, of which there exist more than one capable of practical application.

As instances may be mentioned the filtration at Wakefield, where, for many years, by the use of Spencer's magnetic carbide of iron, a water very much contaminated was rendered perfectly wholesome; and that at Antwerp, where Professor Bischof's spongy iron is employed

with an equally good result.

2. Essential as it is to ensure that the source of supply is proper for the required purposes, it is equally essential that the mode of distribution shall be such as shall prevent its deterioration before be-

sary that the reservoirs, into which the water is collected for distribution, should be covered, and that the mains and pipes should be perfectly air-tight, and laid at a proper depth below the surface, so as to preserve the water in its original state of purity, and, as much as possible, at the same temperature, during its passage from the source to the con-

One great cause of the complaints of The process invented by Professor the quality of the water in most large towns, is the use of cisterns for storing it in the houses, which it is impossible to employ without the risk of some injurious

effect upon the water.

In the Session 1877–78, two bills were introduced into Parliament, at the instance of the Metropolitan Board of Works, for purchasing the undertakings of the London water companies, and for providing a separate supply of drinking water from the chalk. During the exhaustive examination of the waters supplied by the companies, made by the eminent gentleman who so fitly and ably occupies the chair, Sir Frederick Abel, assisted by Dr. Dupré, Mr. G. H. Ogston, Professor Voelcker, and the late able chemist of the Metropolitan Board, Mr. Keates, it was found that, whilst the water delivered in the mains was in almost every case excellent, the position and condition of the cisterns too frequently rendered it utterly unfit for human consumption. A great number of cistern deposits from all quarters of London were examined by these five gentlemen, with the general result just stated.

It is scarcely credible that the favorite place for fixing the cistern, from which the water for drinking and culinary purposes is drawn is immediately over the water-closet or next to the dust hole, whilst even in the better class of houses, where the cisterns are fixed in the roofs, they are very rarely sufficiently covered, and are open to contamination from soot, dust, inroads of black beetles, and other abominations. The latest researches of scientific men show that there is no more fruitful source of disease that such a condition of things affords. Although doubtless, a great deal has been done by the expansion of the system of constant service in London and elsewhere to remedy this frightful evil, the following To effect this, it is absolutely neces-extract from Sir F. Bolton's report for

the month of May shows that there is deterioration of the water above alluded still much room for improvement. He to. says:

"In the monthly and annual reports on the metropolitan water supply, attention is drawn to the necessity which exists for a regular cleansing of cisterns, and also to the fact that contamination of water from gases generated by sewage is of far more frequent occurrence than is generally understood. Water pipes from cisterns are still to be found which are in direct communication with drains, so that gases may flow back into the cistern and become absorbed by the water. To prevent this an overflow pipe should be brought outside each house and the end left exposed to the air, instead of being carried into a drain, as is often the By the adoption of this plan case. poisonous effluvia and gases from drains will be got rid of, which would otherwise ascend through the pipe, and not only be partly absorbed by water in cisterns, but be mixed with the air in the houses, thereby becoming a cause of disease.

"The attention of consumers has been drawn to the fact that, in houses supplied on the constant system, all danger of drinking stale or contaminated water from cisterns may readily be avoided if the following recommendation is carried into practice, viz., to attach a small drawoff tap to the communication pipe which supplies the cistern from the main in the street, from which water may be drawn at any moment, day or night, direct from the works, thereby taking full advantage of any efforts made by the companies to purify the water to the utmost extent. This water should be used for drinking and cooking, and the contents of cisterns made use of for washing, flushing, baths, and similar purposes."

An abstract from these reports of the water examiner is printed by the companies at the back of the collectors' rate papers, so that no consumer of water can now be exonerated from the charge of negligence if this abuse is allowed to continue in his house.

3. This consideration naturally leads up to the third division of the subject, viz., the conditions under which water should be used. And first, it is essential that a constant supply should be given,

Not only is it impossible to give an adequate supply by the intermittent system without having storage cisterns in the houses, but there is also a serious danger of contamination by the possible admission of foul air or gas into the mains when the water is turned off. have been several instances of a water supply being seriously affected from this cause.

But to give constant service it is absolutely necessary, also, that the supply should be under proper regulations, which shall ensure the prevention of undue consumption and misuse of the water.

Not only are the difficulties of providing the supply greatly increased where waste is allowed to prevail, but the cost to the community is augmented without the slightest corresponding benefit to health.

Nothing is more fallacious than the idea, prevalent among a large section of consumers of water, that the allowing of taps and waterclosets to run to waste assists in the flushing and cleansing of the sewers, and therefore conduces to health. These continuous dribblings of water can have no effect whatever in removing any obstruction or accumulations which may exist in the large drains. The only proper and effectual way of removing fecal matter is so to regulate the use of water that it shall be proportionate to the work it has to do at the moment. Where this is done, by the use of properly constructed waterclosets, well-proportioned drains, and by keeping out from the system of sewers the rainfall on the streets and houses, the ordinary quantity supplied to a town is quite sufficient to perform this service without having recourse to extraordinary means. The question of dealing with the sewage of large communities, which is now so full of difficulty, would be much more easy of solution if these principles were more generally acted upon.

For these reasons, it is not desirable that the supply should be unlimited in quantity; on the contrary, every precaution should be taken to make that quantity commensurate with the real wants of the consumers.

It is quite certain that in almost every without which it is difficult to avoid the town a very large proportion of the water delivered through the mains runs need-

lessly to waste.

To take an example on the largest scale, the quantity supplied to London, according to Colonel Sir F. Bolton's return for the month of May, amounts to 32 gals, per head per day, about 20 per cent, of which, or say 6 gals., it is estimated is used for other than domestic purposes, leaving 26 gallons per head as the quantity supposed to be absolutely consumed in the houses. Now it has been ascertained that, on the average, the water really required is not half this quantity; and there is also no doubt that, by taking proper precautions, the amount delivered can be made to approximate very nearly to the actual use.

At Liverpool, by means of careful inspection of fittings, aided by the use of Deacon's meter, a most ingenious arrangement, by which it is easy to localize, and therefore detect, waste, the consumption of water has been reduced from 33 to 22 gallons per head per day, and, within my own experience, the adoption of the same system has, in six or seven instances, produced even more satisfactory results.

The waste of water, whether it arises from leaky joints in the mains and service pipes, or from defective fittings inside the houses, can only be injurious to health from the increased humidity which is thereby imparted to the soil and atmosphere, and which, as is well known, contributes so much to the spread of infectious diseases and the establishment

of epidemics.

At this moment, when we are suffering to a greater extent than usual from the contamination of the Thames, owing partly to the presence of a large quantity of sewage, but also to the abstraction of so large a proportion of the summer flow of the river, it is manifest that amount drawn from and discharged into the river would go far to ameliorate the condition of things now complained of.

Among the different proposals which have been made for the introduction of a system which would ensure the preven-growth of the population of this kinggrave objection that, in order to save sity. Vol. XXXI.—No. 5—27

money, people would be tempted to go to the other extreme, and to content themselves with an insufficient quantity. To obviate this, some such arrangement as that proposed by the writer to the Select Committee of the House of Commons, over which Mr. Ayrton presided in 1867, might be effectual. The following extract from the evidence given before that committee will explain the proposal:

"I think a better method altogether might be devised of supplying the houses in London with water—a better system might be adopted to prevent waste. should provide a constant service by meter, but under different conditions to any hitherto proposed. I think it could be designed with perfect fairness to the water companies and to the consumers, by making certain arrangements, and the general principle upon which I would propose that what should be done would be this: that there should be a sliding scale adapted to the class of house, each house should have a certain amount of water allotted to it. I would take a £100 house, and allot to it 150 gallons per day, and to a £200 house I would allot 300 gallons of water per day, and so on, upwards and downwards, provided that no house should have less than 50 Let the companies charge the same rate as they do now for that minimum quantity of water, and if more is consumed or passes through the meter the consumer would have to pay for that additional quantity."

Although at first sight the expense of the meters would appear to be prohibitive, both the consumer and supplier would soon be reconciled to the outlay, the one because he would know what he was paying in proportion to the water he received, and the other because they were only supplying water for which they were

paid.

The consideration of the subject of this the reduction by 33 per cent. of the paper would not be complete without a reference to the important question of the conservancy of our rivers.

It is useless to discuss the method and conditions of supply, if the sources of water are not to be preserved to us, and it is quite certain that, with the immense tion of waste, is that of furnishing the dom, it will not be long before this supply by meter. This is open to the preservation becomes a pressing necesby the Duke of Richmond's Select Committee on Conservancy Boards, in 1877, a very workable scheme was recommended by their Lordships. The Committee

say that:

"In order to secure uniformity and completeness of action, each catchment area should, as a general rule, be placed under a single body of Conservators, who should be responsible for maintaining the river, from its source to its outfall, in an efficient state. With regard, however, to tributary streams, the care of these might be entrusted to district committees, acting under the general directions of the conservators; but near the point of junction with the principal stream they should be under the direct management of the conservators of the main channel, who should be a representative body, constituted of residents and owners of property within the whole area of the watershed.

But although the question of improving the water supply, by preventing the pollution of the rivers, was incidentally mentioned by their Lordships, it is evident that the main object of the report was the prevention of floods, and not the conservancy of water for the supply of populations. Now, it may well be said that the one subject is at least as important as the other, and just as the recurmond's Committee, it may safely be asdry seasons will compel the serious atpart of the subject. We need go no fur- half. ther than our metropolis for the proof flow of the Thames were properly reguriver should not be in a condition which, health.

When presiding over the Mechanical appealed to in Parliament." Section of the meeting of the British Asoccasion the opportunity was taken to to deal with this subject, and that no

In the report presented to Parliament very fully discuss, from a variety of aspects, this question of rivers conservancy, I made a suggestion which, I believe, is worth repeating at the present time. In

my address to the Section it was stated: "When it is considered that many lives are annually sacrificed, either directly by the action of floods, or by the indirect but no less fatal influence of imperfect drainage—when it is remembered that a heavy flood, such as that of last year, or that of the summer of 1875, entails a monetary loss of several millions sterling in the three kingdoms; that during every year a quantity of water flows to waste, representing an available motive power worth certainly not less than some hundreds of thousands of pounds; that there is a constant annual expenditure of enormous amounts for removing débris from navigable channels, the accumulation of which could be mainly if not entirely prevented; that the supply of food to our rapidly growing population, dependent as it is at present upon sources outside the country, would be enormously increased by an adequate protection of the fisheries; that the same supply would be further greatly increased by the extra production of the land, when increased facilities for drainage are afforded; that, above all, the problem of our national water supply, to which public attention has of late been drawn by H.R.H. the rence of a number of wet seasons at that Prince of Wales, requires for its solution time brought the question of the floods investigations of the widest possible naprominently before the Duke of Rich-ture, I believe it will be allowed that the question, as a whole, of the management serted that a corresponding succession of of rivers is of sufficient importance to make it worthy of being dealt with by tention of the Government to the other new laws to be framed in its exclusive be-

"A new department should be created of this, for if, in addition to the saving -one not only endowed with powers of water by the prevention of waste, the analogous to those of the Local Government Board, but charged with the duty lated by works in the higher parts of its of collecting and digesting for use, all the watershed, there is no reason why the facts and knowledge necessary for a due comprehension and satisfactory dealing although leaving very much to be desired with every river-basin or watershed area in the way of improvement, would yet be in the United Kingdom-a department tolerable, and, according to past ex- which should be presided over, if not by perience, absolutely not injurious to a Cabinet Minister, at all events by a member of the Government who can be

It is earnestly to be hoped that no fursociation, at Dublin, in 1878, on which ther time will be lost in passing an Act considerations of a party or private nature will be allowed to prevent a scheme being made as complete and comprehensive as possible.

In conclusion, as I commenced by thing new; indeed the subject has al- question.

ready been in the hands of far abler exponents than myself; especially would I of so important and imperial a character refer to Dr. Frankland's very able and comprehensive Sixth Report of the Rivers Pollution Commission, the careful study of which is recommended to everybody saying, I have not attempted to say any- who wishes to master the details of the

SPONTANEOUS COMBUSTION IN COLLIERIES.*

By -. DURAND.

From Selected Papers of the Institution of Civil Engineers.

renheit, go on heating more and more till at length it takes fire.

Pyrite met with in coal-seams is either amorphous or crystalline, and occurs in the shape of nodules, flakes, bunches or veins, while sometimes it is so finely disseminated throughout the coal as to be invisible. In dry air and at low temperatures it does not oxidize; but its dissemination through coal or shale gives it a more porous character than appertains to it by itself, and in almost all cases it oxidizes in moist air and becomes converted into sulphate of iron, the excess of sulphur being set free. heat developed by the oxidation is further augmented, where there is sufficient moisture present, by the subsequent conversion of the sulphate of iron into hyposulphate, with liberation of sulphu-

Causes.—The primary causes of fires ric acid, which, when mixed with onebreaking out in collieries where the coal quarter its weight of water, rises to the is contaminated with pyrites are believed temperature of 220° Fahrenheit. Vaby the author, who is engineer of the rious other chemical actions also con-Doyet Collieries, in the department of duce to the development of heat; while Alier, France, to be the three following: there is no absorption of heat by the Oxidation of pyrites, friction from slippings, and warmth of air current. Extion of the pyrites. At Doyet Collieries periments made by Mr. Fayol have the roof over the thick seam of coal is shown that above ground a heap of Com- composed in some places of fine shaly mentry small coal, presenting to the air sandstone containing pyrites; and near a surface of not more than about $1\frac{3}{4}$ the outcrop, where cracks have occurred square yard per cubic yard, will, if once in the roof, the moisture from the surit gets heated to a temperature that lies face and the air from the mine, penesomewhere between 140° and 212° Fah- trating into them, have caused the roof to get red hot, and to set fire sometimes to the timber props. A mere bunch of pyrites, however small, occurring either in the coal itself or in a shale parting, is quite sufficient to serve as a lucifer match for starting a conflagration. The sulphur liberated by decomposition of pyrites burns at 480° Fahrenheit, and any sulpho-carbons which may also be formed burn at about 660° Fahrenheit; whilst the hydro-carbons of coal will not burn below 930° Fahrenheit at least. Hence pyrites, as furnishing the most inflammable products, are really what give the start to a fire.

Where pillars of coal become cracked and crushed under the pressure of the roof, slippings occur, producing considerable friction, which develops corresponding heat; and, as the surfaces sliding past each other are uneven, the friction and heat are concentrated upon the prominences in contact. The heat thus becomes sufficient not merely to accelerate the action of pyrites, but possibly to ignite coal seemingly free from

^{*} The original article appeared in "Bulletin de la Société de l'Industrie Minérale," 1883, vol. xii., pp.

^{**}Solution of the collieries in the Midland and other coalfields of France the
seams are not only of great thickness, sometimes even
more than 20 yards, but are also inclined at steep angles, sometimes nearly vertical.—A.B.

slip of the ground above.

coal in the roof is particularly liable to ter. and moist current.

may become sufficient to fire the gas, and been got out previously.

thereby the coal.

the coal contain pyrites or not, it is more or later to break out. oxidation of pyrites, pressure and subsite the pungent wood smoke gives immedidence of roof, and oxidation of hydro- ate warning of the fire. carbons through condensing power of one containing much more.

Development.—The development of spontaneous combustion is considered rubbish, but the ground is left to fall in, by the author firstly in the case of masses there is certain to be fire if any crushed of coal, such as pillars left in working, coal is left behind. The danger is liable Really solid pillars never fire; those that to be enhanced by accumulation of explodo are always fissured with numerous sive gas in the large cavities; as is the cracks, and are more or less crushed. case also wherever cavities result from

pyrites, even anthracite hard to burn. In Outbreaks of fire are encouraged by the the open working at the outcrop at Doyet presence of any coal crushed small, the coal has been set on fire by a sudden which, in its finely subdivided state, promotes the chemical actions that induce An air current that was warmed by un-heating. Fire first smoulders at the botcondensed steam discharged from an un-tom of the innumerable cracks by which derground engine at Doyet caused a little the pillars have become fissured under small coal, which had accumulated the crushing load they have to support; against some timbering, to get so hot then the walls of the cracks get red hot that the timber took fire after the engine and burn, sometimes bursting suddenly had been at work rather more than three into flame where the previous heating months. In return air-drifts the crushed has covered them with bituminous mat-The tarry smell thus occasioned heat under the influence of the warm often betrays the existence of fire before it has become visible; and so difficult is In seams free from pyrites the author it to find its actual seat, that often it is believes oxidation of the hydro-carbons on not discovered until it has crept outward exposure to air cannot develop heat towards the air current at the mouth of enough to ignite the coal, and the only the chinks, and has ignited the crushed way in which he can account for spon- coal behind the timbering of the roads, taneous combustion in such coal is by and then the timbering itself. The danthe presence of dust or fine slack in the ger is augmented wherever there are midst of any heaps that are found to be timbered excavations overhead; and still heating. Dust and fine slack he consid- more wherever a timber drift has been ers capable of exerting a condensing pushed forward under a mass of crushed power upon the combustible gases that coal overhead. Through such a mass are ready to escape from bituminous or air circulates easily, heat and moistgaseous coal, and also upon the oxygen ure collect there, and fire breaks out of the air; and the heat so developed quicker than where the overhead coal has

Wherever crushed coal can be har-While, therefore, spontaneous combus-bored on or amongst the rubbish that is tion may occur in any colliery, whether packed into the goaf, fire is sure sooner It begins at particularly in seams of caking coal, con-some distance in from the roads, and taining pyrites that, as the workings pro- creeps out gradually towards them, iggress, the pillars left standing grow hot niting on the way any timber that may rapidly, under the combined action of have been left buried in the gob-packing;

Pillars purposely left unworked, either dust. It is the pyrites, however, which, for maintaining a shaft or because the wherever present in any appreciable coal in them is not good enough, are quantity, play the principal part in start- also liable to take fire. The road bears ing ignition, and thus constitute the unevenly around them, they crush and primary cause of fire; the other causes crack under it, and small crushed coal acare then but secondary, although they cumulates next to the gob-packing; the may so far supplement the start thus heavier the pressure the sooner do the given as to make a seam containing but pillars heat and fire. Similar circumlittle pyrites appear readier to fire than stances occur where a nip in the seam stops the getting of coal.

Where the goaf is not packed with

the author considers this can only occur would be prevented. in a moment.

ready to ignite.

to spontaneous combustion. In very places, or along return air ways when the air is warm and moist. pillar of bad coal had stood without heating for seven years at the foot of an incline in a current of fresh air from the cessive courses or steps, one below andowncast shaft, an alteration in the ventilation exposed it to the return current of ing in the goaf, not even were it masonry, warm moist air, and it then got so hot in two months as to necessitate its speedy removal; by the time it could be worked, it was already too hot to touch in some ways more or less crushed. A partial places.

The nature of the roof tells variably. In some collieries fire is found to break out more readily under a roof of tender in leaving a sufficient thickness of coal shale than under one of thick, hard sandthick sandstone roof, settling unevenly after the workings, leaves roof cavities, in which air circulates and encourages it and packing the goaf of the lower heating; while in places where a ceil- working also; or again, in timbering the ing of shale separates the coal from the floor of each course so thoroughly as to

dangerous cavities are left.

ground from the pit mouth is liable to ing a low output with a large proportion heat and fire by oxidation under the action of the air and wet, wherever the in obviating spontaneous combustion; smaller stuff that collects at the top of still less so when the goaf is not packed the heap is combustible enough. The at all, but is left to fall in. fire breaks out first a little below the top, on the side most exposed to the wind; actual outbreak of fire; so long as the and spreads thence throughout the en- coal is merely heating, the small quantity tire tip. It is sometimes started direct of noxious gas given off hardly matters, from the braziers burning at the pit- and the only drawback is that the workmouth to light the landing of the cages; ings sometimes get inconveniently hot the tip then ignites first at the top, for the men. The longer all risk of firing whence the fire spreads downwards and can be staved off, the more possible will laterally.

could only be preserved from getting cost, namely, in seams inclined at steep

settlement of rubbish packed in the crushed and fissured by increased pressure in working, or at any rate if all ac-As to collieries being set on fire from cess of air could be cut off from it when a lamp or an explosion of fire-damp, so injured, its spontaneous combustion In the rare cases where the mass so ignited has got very of quarrying an outcrop, the coal, as long hot beforehand, and is ready to catch fire as the over burden can be removed, can An explosion, moreover, be worked in successive courses or steps throws down a lot of coal that will easily from the top of the seam downwards, take fire, besides shaking and splitting and can thus be got whole throughout the pillars, and so rendering them more the entire thickness of the seam. If the over burden be sent down the pit to Hard seams of caking coal, containing serve as rubbish for packing the goaf in much gas and pyrites, are the most liable underground workings progressing simultaneously, the open-air working can be fiery seams the author has noticed that continued to a somewhat greater depth: heating occurs generally in the dampest at the risk, however, of finding that the deeper coal so reached has been already Where a injured by settlement due to the underground operations.

When coal is got underground in sucother from the top downwards, no packwill entirely prevent settlement of the superincumbent mass, whereby the coal in the lower and later-worked steps is alremedy consists either in packing with rubbish of a clayey nature, which consolidates into a more compact mass; or underneath the packing of the goaf in At Doyet, on the contrary, the the topmost course, and afterwards getting out as much as possible of this thickness, by working backwards below thick sandstone, the shale falls, and no form a roof for the subsequent working of the next course below. But these Coal or rubbish tipped in heaps above methods, besides being costly and yieldof small coal, are not always successful

What has to be guarded against is an it be to adopt the mode of working that Prevention.—If the coal in a seam will yield the largest output at the lowest

angles, by laying out the workings in most liable to occur at junctions of roads, of heating and firing. But in the upless crushed by the augmented pressure; any crushed pillars that have been abanhence, to avoid fire there must be some limit to the total height of each panel, or greater height than the upper. In a expansive, pillars get less crushed, and thick and well stratified seam of strong are therefore less liable to heating, and coal, containing not many partings, and fewer dangerous roof cavities occur in inclined between 14° and 30° to the which an outbreak of fire would be diffihorizon, the total height of each panel cult to extinguish. In packing commay be 26 yards, measured up the slope, posed of friable stuff, the smaller bits fill and the height of the bottom course 8 up the spaces between the larger; and, yards. But in the main seam at Doyet, if of a somewhat clayey consistency, the which, though hard, is of variable qual-ity and too liable to fire, the height of solid mass impervious to air. Good the courses is only that of a singe tier packing of this kind should always be of timber props, say 2 to 3 yards. Here used in the bottom courses of each four courses can be got, and a fifth panel; then by the time the top course started, without any fire having broken is reached in the next panel below, the out; only no course must take more than coal will there be got under a roof as six months in getting, and all the goaf compact as solid sandstone. must be thoroughly filled in. Quick getbroken coal it contains is already hot, can pass too freely amongst them. and great care is needed to prevent its working a panel where the bottom course burning whilst getting; hence five had been wholly packed with spoil got as the third course from the bottom is spoil itself was incapable of heating, the next panel below; if the working of the midst of this spoil because not worth lower panel were begun sooner, that of getting, grew hot so rapidly as to be the upper would be endangered by settle-taking fire by the time the second course ments.

avoid the formation of roof cavities, rammed in, that the winning of the coal from which start cracks that radiate could be finished to the top of the panel. through the seam; such cavities are Some years later, when the working of

successive stages or panels of great and are to be guarded against by careful height (measured up the slope), which timbering, which must be well watched. entails less expense for the preparatory Large cavities occurring in spite of these operations of laying them open; several precautions should be cleared out, and of these stages are then worked sim- then thoroughly filled in with good packultaneously, the getting of the coal being ing of small rubbish brought from proceeded with in each stage from the above ground. Where gob roads have bottom upwards, by a succession of hori- to be kept open for working or ventilazontal courses or excavations. By this tion, they should either be shifted so as method the bottom courses in each panel not to run through the middle of the feel the roof-pressure least, and yield a goaf, but along its margin; or else they great quantity of large coal, which is should be walled thick enough with good won without difficulty, and with less risk packing impervious to air and moisture, particularly when used as airways. They permost courses the coal gets more or should be kept at a safe distance from doned in working.

The advantages of packing the goaf rather to the number of courses con- with rubbish are, that the workings are tained in it, the bottom courses being of thereby kept cooler, settlements are less

Spoil got from stone-drifts should not ting is indispensable for avoiding fire in be used for packing the goaf; the large seams that fire readily. Usually by the blocks of stone are too hard to crush time the fifth course is reached, the under any settlement overhead, and air courses would seem to be the general from sinking a shaft and from driving limit for the height of a panel. As soon stone-drifts, notwithstanding that the being got in any panel, the getting can author found that pillars of considerable be started of the bottom course in the size, which had been left behind in the was finished and the third begun. It Alike in laying out the roads and in was only by then surrounding this dangetting the coal, care must be taken to gerous goaf with small rubbish carefully

had to be encountered. thor regards any spoil got underground let air-way runs at all near a return airtions are taken to pick out of it all stuff careful watching. that could burn, and even then to keep it

for use as packing. less disintegrated; the former is necessary wherever access of air has to be roof to settle down heavily upon the packing. Where the goaf is well packed with good stuff, the timbers, whether upburied in the packing; otherwise they should be removed, even if only partially, as a precaution against fire. By way of rendering the rubbish tips at the surface sooner ready for use as packing, it is sometimes thought desirable to let them burn as freely as may be. But this opinion is not shared by the author, who very long time to burn through to the middle, but that, after the fire has all burnt itself out, the ashy stuff will be too light, too dusty, too hot, and not binding enough, to be suitable for sending underground. Nevertheless even such burnt rubbish is preferable to spoil got underground and packed there at once.

Ventilation by a forced current of air under pressure has been found by the author to be favorable to spontaneous current, in the midst of crushed pillars passing up the slope from the lower to

the next panel below came in under the or badly packed rubbish, are sources of same place, similar trouble from heating danger, as are also inclines rising steep, Hence the au- and upcast pits. Hence, wherever an inas so bad for packing the goaf, that it way, the intervening pillars or ribs of should never be used unless the precau-seemingly solid coal require specially

The coolness of the air current is pracclear of contact with any masses that tically of no value for preventing, though can heat. It is indeed by no means a it may somewhat retard, the heating of dead loss to send up all such spoil to cracked pillars, or of broken coal that bank and throw it over the tips, where has fallen from roof cavities or elsewhere. after two or three years' exposure to the In a colliery where an old drift 41 atmosphere it may, if meanwhile pre- yards long, from a shaft to an inlet airvented from burning, become good way, had been closed with rubbish careenough to send down again into the pit fully packed, the subsequent settlement of the packing had left a space above, The best packing of all consists of into which a little crushed coal had fallen loamy earth, and surface strata more or from the roof; the coolness of the ingoing air did not prevent this slack from heating and beginning to burn; and it stopped at once without waiting for the had to be all cleared out, and earth rammed in its place.

A return air-current should never have to go downhill, otherwise it accumulates right props or roof slabs, can be left be- heat and moisture at the upper end of hind to become crushed by the load and the descent, thereby favoring spontaneous combustion at that place. Where distant workings are liable to be insufficiently ventilated, owing to negligence in maintaining former roads, now used as airways only, fresh air should be supplied direct to them, either by splitting the main ingoing current, or by sinking a new shaft from the surface. It is better considers that not only will a tip take a to split the air than to course a single current through too great a length, because the latter means greater difference of pressure, attained with more risk of

At the Doyet collieries, wherever the seam is not thick enough to work by the foregoing method of horizontal courses, and where the expense of laying out the workings on that method would be too great, the plan is followed of getting the coal in inclined courses, that is by pushing the working faces forwards uphill combustion. Whether compression or along the slope of the seam, instead of exhaustion be employed, the greater the horizontally along its strike. The uphill difference of pressure between the en- courses however are more difficult to tering and the return air-currents, the keep open, and are liable to worse falls; more readily will the air penetrate each course takes longer to get, so that cracked and crushed coal, and thereby the surrounding crushed coal runs promote heating and firing. In this regreater risk of heating. And this risk spect, sharp turnings or narrowing of is further enhanced by the augmented roads, and air-doors situated in a strong draught consequent upon the air-current

the upper end of the course; hence refuse slimes from the coal-washers. fire breaks out more readily, while it is also more difficult to contend with on the slope than in horizontal workings. On the other hand, the rather larger quantity of packing used in uphill than in horizontal courses is an advantage against fire.

Firing of slack-heaps above ground can be effectually obviated, in the author's opinion, only by completely precluding all penetration of air into them. To ventilate them, with the idea of keepence of its success in smothering fires should be left long enough exposed, be-on the sloping banks of out-crop work-ings, he recommends the expedient of be also freed beforehand from all that covering the slack-heaps with a layer of can be utilized, so much the better coal.

such a covering, being coaly and not clayey, does not set hard and crack, but follows readily any subsidence of the stuff beneath it. A layer 12 inches thick he believes would be an ample protection against firing, or even heating; and he suggests that on shipboard spontaneous combustion in coal cargoes might be altogether obviated by a layer 6 inches thick. the coal being so stowed as to prevent the covering of slimes from disappearing into the interstices. ing them cool, he considers as ineffectual prevent spoil-tips from firing, the stuff and as dangerous as to let air penetrate should be tipped in a layer too thin to crushed coal in the pit. From experi- heat under the action of the air; and

THE BAROMETER AND THE WEATHER.

ABSTRACT OF A MANUAL ISSUED BY THE AUTHORITY OF THE METEORO-LOGICAL COUNCIL.

From the "Nautical Magazine."

of 30° and 40° north, and according to Buys Ballot's law, the wind draws round it, being northerly on its eastern, easterly on its southern, southerly on its western, and westerly on its northern side.

from England, say, to the Cape of Good Hope, passes from the north-east to the east and south-east side of an area of high pressure lying to the westward of him, and as he approaches the coast of Portugal, the wind very generally comes from north-west, gradually shifting to north and north-east as he proceeds to the southward.

On the other hand, when a homeward-ing circulation of the wind round it. bound ship approaches the northern

THE Atlantic Ocean will supply types calls them, "Doldrums of Cancer." There of the winds usually met with in other being no difference of pressure there is seas. An area of high pressure occurs in no wind, and these calms coincide with a the North Atlantic between the parallels large area of high and even pressure, where a ship will experience little or no wind until she has crept to a part of the sea where the pressure commences to decrease.

If, as occasionally happens, it is found A seaman, therefore, outward bound that the N. E. Trade gradually turns into a S. E., S., and S. W. wind, it will be understood, from what has already been said, that a vessel experiencing these changes has passed round the S. W., W., and N.W. sides of this area of high pressure, thereby avoiding the region of calms altogether.

There is a similar area of high pressure in the South Atlantic, with a correspond-

The homeward-bound ship, after roundverge of the N.E. Trades, she finds that ing the Cape of Good Hope, is at the the wind draws to the eastward, with a polar edge of the S. E. Trade on the rising barometer. As the area of highest eastern side of the South Atlantic, just pressure is reached the barometer ceases as the outward-bound ship is at the polar to rise, and the wind dies away. These edge of the N. E. Trade when off the are the dreaded "calms," or, as Maury coast of Portugal, and the first wind she experiences is from S. W., changing to S. and S.E. as she proceeds to the northward, which (according to Buys Ballot's law, when applied to the southern hemisphere), shows that she has passed along the S. E., E., and N. E. sides of an area

of high pressure.

Again, the outward-bound ship, as she draws towards the southern verge of the S. E. Trades on the western side of the South Atlantic, very generally experiences changes of wind to N. E., N., and N. W., which are the winds met with in the southern hemisphere on the N. W., W., and S. W. sides of an area of high pressure, corresponding to the winds already noticed as being experienced on the western side of the North Atlantic.

Areas of high barometrical pressure occur in many other parts of the ocean, similar to those of the Atlantic, and corresponding winds circulate round them.

CYCLONIC GALES OF THE TEMPERATE ZONES.

The great currents of the atmosphere, which give rise to the prevailing winds, are thus seen to be regulated by the positions of the permanent areas of high and low pressure, and in these currents, subsidiary areas of low pressure make their appearance, and are carried along with them, and these traveling areas fre-

quently give rise to gales.

In the temperate zone of the North Atlantic these gales, which almost invariably travel to the eastward with the prevailing atmospheric current from the west, generally commence at S. and end northern hemisphere the lower barometer at W. or N. W., with little or no E. wind. The probable reason of this is that the areas of low pressure to which they are related have steep gradients only on their E., S. E., S., and S. W. sides, there being little or no difference of pressure between their center and the more permanent depression which lies to the north of them.

The ordinary gales of high southern latitudes are similar in character to those of the northern hemisphere. They also accompany areas of low pressure traveling to the eastward, and considering that an equatorial wind is here north instead of south, the winds are similar, for they commence at N., and end at W. or S. W., with little or no easterly wind, probably because the pressure to the S. is so much lower than that to the N. of the tract in which they occur.

The cyclonic storms of the Temperate Zones do not often present the phenomena of a central calm, with the winds blowing from nearly opposite directions on each side of it. There is, therefore, not so much risk of being taken aback as in the tropical cyclones; but it is advisable for a captain to know on which tack it will be safest to lie-to if obliged to do so, and this will be the same as that for the cyclones of the respective hemispheres.

The most serious sudden shift of wind which is to be expected in these storms is that from south-west to north-west in the northern hemisphere, or from northwest to south-west in the southern. This is generally accompanied by heavy rain or hail, with thunder and lightning, while the temperature falls several degrees with the first blast of north-west or south-west wind, as the case may be, according to

the hemisphere.

In considering how to act in such circumstances, there are two matters to which the seaman's attention should be directed, as they seriously affect the conclusions he should draw from his barom-

eter readings.

The first is that on the one tack his barometer has a tendency to rise, on the other it has a tendency to fall. The tack of rising barometer is the starboard in the northern, the port in the southern hemisphere. This may be explained as follows :-

According to Buys Ballot's Law in the is on your left when your back is turned to the wind, and as when you are thus placed a ship on the starboard-tack is advancing towards your right, she goes towards the higher barometer and recedes from the lower. In the southern hemisphere this is reversed, and the ship on the port-tack advances towards the higher and leaves the lower barometer.

But this rule will only be strictly applicable so long as no change takes place in the barometric pressure, and it may so happen that a high pressure towards which the ship is going may be receding from her faster than she sails, and a lower pressure may be coming up astern and overtaking her; or it may be that a lower pressure towards which the ship is sailing may be moving away faster than she sails. Still the influence of the tack must

always be felt, and on the whole it may pens during a heavy shower of rain, tobe said that in the northern hemisphere, gether with a sudden fall of temperature), a rising barometer on the starboard-tack when the barometer will probably rise as is not sufficient indication of improving fast as it previously fell, and a strong N. weather, and other signs should be looked W. wind will set in. for before trusting it. In all cases for the northern hemisphere a rising barom- clear to the navigator that in northern eter on the port-tack is a valuable indication of improving weather, while a falling wind, a sailing ship as well as a steamer barometer on the starboard-tack is an bound to the westward will, by her course important warning in the other direction, and speed, cause the barometer to fall This order is reversed in the southern hemisphere.

The second point to consider is the relation which the course and the speed of lought to be considered, or her captain of the areas of low barometric pressure than is really coming. and their corresponding wind-systems, in erly direction.

ten miles an hour.

In other words, ships when outward do herself more harm than good. bound across the Atlantic meet the adthan in the latter.

GALES OF THE NORTH TEMPERATE ZONE.

be hove-to or stands to the westward, the meet these risks. barometer will fall until the wind shifts to the westward (which generally hap- the starboard-tack takes her away from

From what has been said it will be latitudes, at the setting in of a southerly quicker than if she hove-to or stood to the eastward, so that in this case also the state of the sea and other appearances the ship bear to the tracks and progress may be led to anticipate worse weather

With a southerly wind and falling parts of the sea where the general tracks barometer, a ship bound to the westward of storms are known. This will be easily might gain by running to the northward done by taking, as an illustration, the with the object of causing the wind to case of a steamer traversing the North back to the eastward, but the type of Atlantic between England and America, gale in which this is possible resembles a where storms generally move in an east-cyclone, and does not represent the ordinary gales of these latitudes which begin If a storm is advancing eastwards at at S. and end at W. or N. W. Again, it the rate of, say, twenty miles an hour, might be possible for a ship, with the and if the ship is steaming at the aver- first of the southerly wind which exists age rate of, say, ten miles an hour, the on the east side of the area of low pressresult will be that when going westward ure, to get less wind by running to the the ship will have a relative rate of mo-north, but as the extent in latitude of the tion towards the storm of thirty miles an 'cyclone area is not known, and as there is hour, but when going eastward, of only no certainty that she would get into more moderate weather by doing so, she might

It seems, then, probable that a ship vancing storm systems, which commonly bound to the southward or westward travel from west to east, and when home- must face one of these gales if she meets ward bound run with them, consequently it. A weak ship, whose object is to stem the rapidity with which the barometer the sea and get safely through, without falls or rises and the wind shifts is pro- considering progress, should lie to on the portionately greater in the former case starboard-tack, as the wind generally shifts from S. to S.W., W. and N.W. This would of course be the best plan for any ship which found the gale too The ordinary gales of the north Tem- heavy for her. But a well-conditioned perate Zone commence at S. E. or S. and ship, bound to the westward, may end at W. or N. W. If a ship in these keep on the port-tack until the wind latitudes experiences a fresh S. or S. E. shifts to west with a rising barometer, wind, with a relatively high temperature and then tack to the south-westward. and falling barometer, Buys Ballot's law This plan would, of course, tend to bring shows that there is an area of low press- her into the trough of the sea, and she ure to the W. or S. W. of her; and it is would be more likely to be caught aback probably traveling to the E. or N. E. as the wind changed, but we are assum-Experience shows that whether the ship ing that her captain will be prepared to

When the wind has shifted to N.W.

of the eastern side of another low-press-take her into the northerly wind of the ure-area coming toward her. This would be a very common occurrence in winter.

GALES OF THE SOUTH TEMPERATE ZONE.

The prevailing gales of high southern latitudes resemble those of northern, and in describing them it is only requisite to remember that there north and south change places. For instance, as a ship bound to Australia gets into 40° S., "the Roaring Forties,"she experiences a series of gales which, commencing at N. or N.E., end at W. or S.W. Now with a northerly wind in the southern hemisphere there is a low pressure to the westward, and port-tack. the way in which the wind usually changes proves that those areas of low pressure are also traveling to the eastward. Ships which keep a steady westerly wind for days, as they run to the eastward in high southern latitudes, are probably keeping company with one of these areas of low pressure, and if they had hove-to or commenced beating to the westward they also would have experienced many changes, just in the same manner as our steamers bound to America do, whilst those from America frequently keep a steady barometer and westerly wind for days. This receives abundant confirmation from the experienced within 5° or 6° of the Equafrequency of the barometrical oscillations and changes of wind, experienced by high latitudes. They appear to be most ships bound to the westward, in rounding frequent and most severe in the West either the Cape of Good Hope or Cape Horn.

The best method for dealing with a heavy gale, or with a weak ship in an ordinary gale, is reversed for high southern latitudes; there the port is the "coming up" tack, which enables her to stem the sea, as the wind usually shifts from N. by N. W. to S.W., and the port-tack Bengal cyclones occur most frequently

the center of such a disturbance, though lated, though of course it may, and in the she may soon sail into the southerly wind winter months most probably will, soon eastern side of another low pressure coming towards her.

> For a ship beating to the westward, of course the best progress is made by keeping on the starboard-tack with the wind N. and N.W. until it shifts to W. and S.W., when she ought to tack to the north-westward; but it will be seen that, as in the best method for making progress to the westward in high northern latitudes, the ship will be headed off, and get into the trough of the sea; she will also be more liable to be taken aback, as the wind changes, than if she were on the

> > TROPICAL STORMS.

HURRICANES, TYPHOONS, OR CYCLONES OF TROPICAL SEAS.

Of all atmospheric disturbances, of the approach of which the barometer can supply indications, and the dangers of which it may enable the seaman to avoid, by giving him warning of their proximity and position, the most serious are the re-

volving storms of the tropics.

These storms, all of which may be properly termed cyclones, occur in the three great oceans, the Atlantic, Pacific, and Indian Oceans; but they are seldom tor, and have not been traced into very Indies, in the vicinity of Mauritius, in the Bay of Bengal, and in the China Seas; and in these seas they are most prevalent during the months following the summer solstice, or in other words, from July to October, in the northern hemisphere, and in the southern from December to April. In the Arabian Sea and in the Bay of with a S.W. wind takes her away from from April to June, and in October, Nothe low pressure to which the wind is re-vember, and the beginning of December.*

* Table of Reoorded Hurrioanes, Cyolones and Typhoons, in Various Parts of the World.

	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oet.	Nov.	Dec.	Total.
West Indies, 300 years South Indian Ocean (39 years,	5	7	11	6	5	10	42	96	80	69	17	7	355
Bombay, 25 years. Bay of Bengal, 139 years.	9 1 2	13 1 —	10 1 2	8 5 9	4 9 21	$\frac{-}{2}$	4 3	5 4	1 8 6	1 12 31	4 9 18	- 5 - 9	53 62 115
China Sea, 85 years	5	1	5	5	11	10	23	40	58	35	16	6	214

They are commonly known as hurricanes in the West Indies; cyclones in the Indian Ocean; and typhoons in the China Seas.

The space over which these storms have been known to expand themselves varies from twenty or thirty miles to some hundreds of miles in diameter; the wind blowing with an ever varying force, now lulling into little more than a strong breeze, and as the center is approached often rising into a blast of irresistable fury.

It is an invariable characteristic of their revolution, that the gyration of the storm field takes place in one direction; in the northern hemisphere in the opposite direction to the hands of a watch, and in the southern hemisphere with the hands of a watch. The knowledge of this law is the more important, as it not only supplies the seaman with direct means of distinguishing these storms from gales in which the direction of the wind varies little if at all, but it reveals to him the position of the center or vortex with respect to the place of his vessel, and therefore points out the way to avoid it, and so to escape from the region of greatest danger, where the fury of the wind is most extreme, the changes of its direction most sudden and the sea most to be dreaded.

In the Atlantic and South Indian Ocean these storms commence to the eastward; for some days they travel along a path not exactly west, but inclining a point or two towards the pole of that hemisphere which they are crossing; and as they advance they seem more inclined to curve away from the equator. When they reach the 25th degree of latitude, they generally curve still more, until they move to the N. E. in the northern hemisphere, and to the S. E. in the southern hemisphere. The Atlantic storms almost always wheel round to the northward in the Mexican Gulf, or in its vicinity, and follow the sea-board of North America.

The cyclones of the Bay of Bengal appear to originate near the Andaman Islands, those of the Arabian Sea near the Lacadives. These generally travel to the westward and north-westward, the may bear 10 or 12 points from the direcformer sometimes crossing the Indian Peninsula, sometimes passing off over Bengal, and curving back to the east-

commonly take a westerly or north-westerly course.

The rate of movement of these storms, though variable, may be averaged at 300 miles a day in the West Indies; in the Arabian Sea, in the Bay of Bengal, and in the China Sea, 200 miles a day; whilst in the Southern Indian Ocean their rates vary from fifty to 200 miles a day.

The indications of the approach of a revolving storm are the usual ugly and threatening appearance of the weather which forebodes most storms, and the increasing number and severity of the gusts with the rising of the wind. These signs are in some cases preceded by a long heavy swell, and confused sea, which comes from the direction in which the storm is approaching, and travels more rapidly than the storm center.

The best and surest of all warnings, however, will be found in the barometer. In every case there is great barometric disturbance, the barometer at the centers of some of the storms standing fully two inches lower than outside the storm field. Accordingly if the barometer falls rapidly, or even if the regularity of its diurnal variation be interrupted, danger may be apprehended.

The first care of a master of a vessel caught in a cyclone will be to find how the center bears from him. In the northern hemisphere let him, facing the wind, take eight points to the right of the direction of the wind, and that will be the approximate bearing of the center; in the southern hemisphere take eight points to the left. Thus, in the northern hemisphere with the wind from N. E., the center will bear S. E., and in the southern hemisphere with the wind from N.W., the center will bear S.W.

In the present discussion, the motion of the wind in a cyclone will, for the sake of simplicity, be treated as approximately circular. But this is not strictly the case, and there is evidence to show that frequently in some parts of the stormfield there is more or less indraft. At a considerable distance from the center, and before the barometer shall have fallen much below its normal value, the center tion of the wind (reckoned to the right or left according to the hemisphere); but after the barometer has fallen five or sixward. The typhoons of the China Seas tenths of an inch it is probable that the wind then blowing forms part of the central storm circle, and the bearing of the center may be taken as eight points from the direction of the wind.

It was said that the master's first care will be to know how the center bears. His next care will be to know on which side of the storm's path his vessel is situated, and the direction in which the storm is moving. In the northern hemisphere if she be situated on the righthand side or semicircle of a storm traveling to the westward—looking in the direction to which the storm is traveling the wind will veer N.E., E., S.E., S., &c., or with the hands of a watch; on the left-hand side the wind will back N., N.W., W., &c., or against the hands of a watch.

Similarly, in the southern hemisphere, if the vessel be in the right-hand semicircle of a storm traveling to the westward—looking in the direction to which the storm is moving—the wind will veer S., S.W., W., &c., or with the hands of a watch; in the left-hand semicircle it will back S.E., E., N.E., N., &c., or against the hands of a watch.

In speaking of the shift of wind such a shift is meant as would be observed on a vessel hove-to; for if the vessel be moving faster than the storm, and in the same direction, the shift may be in the opposite direction to what has been stated.

If while the vessel is hove-to the wind be found to remain in the same direction. increase in violence, and be accompanied by a falling barometer, it is probable she lies in the path of the advancing storm—the most critical of all positions.

The wind in front of the storm-field is, from the nature of the case, directed across the path of the center; blowing towards the path on one side, and away from it on the other. Consequently, if we suppose the cyclone to be bisected by a line representing its path, a little consideration will show that in the semicircle on one side of the path, a ship running before the wind may probably be brought to cross the path of the storm in front of its center, and therefore under circumstances of the greatest danger; in the semicircle on the other side of the path a ship running before the wind will probably cross the path in rear of the center. The former of these semicircles of the center of the vortex from a vessel.

has been called the "dangerous" semicircle.

When looking in the direction in which the storm is traveling the dangerous semicircle is always on the right hand in the northern hemisphere, on the left hand in the southern hemisphere; also in both hemispheres in the right-hand semicircle the wind, to a ship hove-to, always veers, the left-hand semicircle it always The semicircle with veering winds is the dangerous semicircle in the northern hemisphere; the semicircle with backing winds is the dangerous semicircle in the southern hemisphere.

The recurvature of the path always takes place towards the side on which the dangerous semicircle is situated, i.e., to the right in the northern, to the left in the southern hemisphere. Hence in the northern hemisphere, so long as the vortex is traveling to the west, the winds in front of the advancing center are northeasterly; as the vortex turns to the north, the winds in front are easterly; and after it has turned to the eastward the winds in front are south-easterly. similar sequence will arise in the southern hemisphere, but in the opposite order, the winds in front of the vortex beginning with south-east and ending with north-east when the vortex has turned to the eastward.

We derive, then, the following rules to find the most dangerous wind, supposing always that the track of the storm is such as is indicated above, recurving in about lat. 30° N. or lat. 26° S.—

NORTHERN HEMISPHERE.

Between the Equator and 30° N.	latN.E.
About 30° N. lat	E.
Northward of 30° N. lat	S.E.

SOUTHERN HEMISPHERE.

Between the Equator and 26° 8	S. lat	.S.E.
About 26° S. lat		
Southward of 26° S. lat		N.E.

These winds are most dangerous, because in each case if the wind continues steady from that point and the barometer continues to fall rapidly the ship must be on the path of the storm and directly in front of it, so that she is in the position of greatest peril.

It is difficult to estimate the distance

This partly arises from the uncertainty as to the relation between the bearing of the center and the direction of the wind, and greatly from there being no means of knowing whether the storm be of large or small dimensions. If the barometer falls slowly, and the weather only gradually gets worse, it is reasonable to suppose that the center is distant: and conversely with a rapidly falling barometer and increasing bad weather the center may be supposed to be approaching dangerously near.

PRACTICAL RULES FOR SEAMEN IN TROPICAL CYCLONES.

When in the region, and in the season of revolving storms, be on the watch for the premonitory signs. Constantly and carefully observe and record the barome-

When there are indications of a cyclone tempts to cross. being near, heave-to and carefully observe and record the changes of the barometer and wind, so as to find the bearing of the center, and ascertain by the shifting of the wind in which semicircle the vessel is situated. Much will often depend upon heaving-to in time.

When, after careful observation, there is reason to believe that the center of a cyclone is approaching, the following rules should be followed in determining whether to remain hove-to or not, and the tack on which to remain hove-to:

Northern hemisphere.—If in the righthand semicircle, heave-to on the starboard-tack. If in the left-hand semicircle, run, keeping the wind, if possible, on the starboard-quarter; and when the barometer rises, if necessary to keep the ship from going too far from the proper course, heave-to on the port-tack.

Southern hemisphere.—If in the righthand semicircle, run, keeping the wind, if possible, on the port-quarter; and when the barometer rises, if necessary to keep the ship from going too far from the proper course, heave-to on the starheave-to on the port-tack.

Both hemispheres.—When the ship lies in the direct line of advance of the storm -which position is, as previously observed, the most dangerous of all—run. most dangerous of all, run to the N.W. And in all cases act so as to increase as

center; bearing in mind that the whole storm field is advancing.

Heaving-to in both hemispheres.—If the ship be in the right-hand semicircle, heave-to on the starboard-tack. In the left-hand semicircle, heave-to on the porttack; these being the tacks on which the ship will "come up" as the wind shifts.

In receding from the center of a cyclone, the barometer will rise, and the wind and sea subside.

It should be remarked that in some cases vessels may, if the storm be traveling slowly, sail from the dangerous semicircle across the front of the storm, and thus out of its influence. But as the rate at which the storm is traveling is quite uncertain, this is a hazardous proceeding, and the seaman should hesitate and consider all the circumstances of the case, particularly observing the rate at which the barometer is falling before he at-

Cyclones of the South Indian Ocean. —The researches of Mr. Meldrum, Director of the Government Observatory at Mauritius, have shown that, in the South Indian Ocean, a vessel approaching a cyclone on its southern side almost always encounters a strong Trade wind, which freshens to a gale. It is difficult to tell when the Trade forms part of the storm circle; consequently the bearing of the center can seldom, in this position, be inferred from the direction of the wind.

It is therefore recommended under such circumstances to heave-to and watch the wind and barometer; when the wind has shifted decidedly to the east or south the passage of the center with respect to the vessel's position may be approximately inferred; and when the barometer has fallen six tenths of an inch its height at the commencement of the storm, the bearing of the center may be taken as nearly at right angles to the direction of the wind.

If the wind shift from S.E. decidedly board-tack. If in the left-hand semicircle towards the south, run to the N.W. Or, if the wind remain steady at S.E., increase in force, the barometer still falling, it is probable the storm is advancing directly towards the vessel; in such case, the

It is also stated that in the cyclones of soon as possible the distance from the the South Indian Ocean, north-easterly

and easterly winds often, if not always, sustained in a cyclone which they entered blow towards the center. Such being the on its northern side. There is a strong case, it is better to make as much easting temptation to such vessels to run on with

as possible.

repairs do so in consequence of damage them to heave-to in time.

a favorable breeze; but a freshening It might easily be shown, the same northerly or north-easterly wind, with a writer remarks, that all the homeward-falling barometer, and threatening apbound vessels that put into Mauritius for pearance of the weather, should warn

PROGRESS IN MECHANICAL SCIENCE.

AN ABSTRACT OF SIR FREDERICK BRAMWELL'S ADDRESS TO THE MECHANICAL SCIENCE SECTION OF THE BRITISH ASSOCIATION.

From the "Journal of the Society of Arts."

met in that city, they arrived there practically the Manchester and Livertion to the fact that in 1831 there were but very few steamers. I find the total registered in the United Kingdom in that year was only 447. If under this condition of things, the proposition had been made in 1832 at Oxford, as it was made in 1882 at Southampton, that the next meeting but one of the Association should take place in Montreal, the extreme probability is that the proposer would have been safely lodged in a lunatic asylum, for suggesting that that which might have involved a six-weeks' voyage out, and a four-weeks' voyage back, could ever be seriously entertained.

There are those I know who object

that Section G deals too little with pure science, too much with its applications. It may be, as the members of Section G might retort, that it is possible to attend so much to pure science as to get into the unchecked region of scientific speculation. . . I think all men, even although they be followers of science in its purest and most abstract form, will concur in the propriety of Section G dealing with engineering subjects generally as well as with abstract mechanical science. meteorological science, photometrical sci-

After alluding to the formation of Once admitting this, I may ask—certain Section H, Sir Frederick Bramwell said: what the answer must be—whether there At our jubilee meeting at York, I called is any body of men who more appreciate the attention of the section to the fact and make greater use of the applications that in 1831, when the Association first of pure science than do the members of this Section. Surely every one must laboriously by the stage-coach, and that agree that we engineers are those who make the greatest practical use, not only pool, the Stockton and Darlington, and of the science of mechanics, but of the some few others, were the only railways researches and discoveries of the memthen in existence. I also called their atten- bers of the other sections of this Associa-

> Section A (Mathematical and Physical Science).—The connection between this section and Section G is most intimate. With any ordinary man I should have referred, in proof of this intimate connection, to the fact that the President of A this year is a member of the Council of the Institution of Civil Engineers; but when I remind you that it is Sir William Thomson who fills this double office, you will see that no deduction such as I have hinted at can be drawn from his dual functions, because the remarkable extent and versatility of his attainments qualify him for so many offices, that the mere fact of his holding some one double position is no certain evidence of the intimate connection between the two. But setting aside this fact of the occupancy of the chair of A by a civil engineer, let us remember that the accomplished engineer of the present day must be one well grounded in thermal science, in electrical science, and, for some branches of his profession, in the sciences relating to the production of light, in optical science and in acoustics; while in other branches,

neer starting with the mechanical equiva- is imperfect; and he will begin to direct knowledge of the calorific effect of dif- fine dust, as by Crampton's process, as ferent fuels, is enabled to compare the re in these conditions the supply may be and to ascertain how far the one falls introduction of air may be easily regushort of the other; he sees, even at the lated with the greatest nicety. He will present day, that the difference is deplor-say, I am obliged to put among my ably large, but he further sees, in the credits—loss of heat by convection and case of the steam engine, that which the radiation, loss by carrying particles of pure scientist would not so readily appreciate, and that is, how a great part of densation with the cylinder, loss by this loss is due to the inability of mate-strangulation in valves and passages, loss rials to resist temperature and pressure by excessive friction or by leakage; and beyond certain comparatively low limits; he will as steadily apply himself to the and he thus perceives that unless some extinction or the diminution of all such hitherto wholly unsuspected, and appar-causes of loss, as a prudent Chancellor ently impossible, improvement in these of the Exchequer would watch and cut respects should be made, practically down every unproductive and unnecesspeaking, the maximum of useful effect sary expenditure. It is due to the guidmust be far below that which pure sci- ance of such considerations as these that ence would say was possible. Neverthe- the scientific engineer has been enabled less, he knows that within the practical to bring down the consumption of fuel limits great improvements can be made; in the steam-engine, even in marine enhe can draw up a debtor and creditor acgines such as those which propelled the count, as Dr. Russell and myself have ship that brought us here, to less than done, and as has been done by Mr. one-half of that which it was but a few William Anderson, the engineer, in the years back. It is true that the daily admirable lecture he gave at the Institution of Civil Engineers in December last that it may have been even greater; but on the "Generation of Steam and the if so, it arises from this, that the travel-Thermodynamic Principles Involved." Furnished with such an account, the en- present the engineer, in his capacity of gineer is able to say, in the language of naval architect, has not seen howcommerce, I am debtor to the fuel for so notwithstanding the great improvements many heat units, how, on the credit side that have been made in the forms of vesof my account, do I discharge that debt? sels—to obtain high speed without a

ence, and tidal laws are all important. Usefully I have done so much work, con-Without a knowledge of thermal laws, verted that much heat into energy. Usethe engineer engaged in the construction lessly I have raised the air needed for of heat motors, whether they be the combustion from the temperature of the steam-engine, the gas-engine or the hot atmosphere to that of the gases escaping air-engine, or engines depending upon by the chimney; and he sets himself to the expansion and contraction under consider whether some portion of the changes of temperature of fluids or of heat cannot be abstracted from these solids, will find himself groping in the gases and be transmitted to the incoming dark; he will not even understand the air. As was first pointed out by Mr. value of his own experiments, and, there- Anderson, he will have to say a portion fore, will be unable to deduce laws from of the heat has been converted into them; and if he make any progress at energy in displacing the atmosphere, and all, it will not guide him with certainty that, so far as the gaseous products of to further development, and it may be the coal are concerned, must, I fear, be that he will waste time and money in the endeavor to obtain results which a knowl- more air than was needed for combustion edge of thermal science would have to pass through the fuel, and I did it to shown him were impossible. Furnished, prevent another source of loss—the however, with this knowledge, the engi- waste which occurs when the combustion lent of heat, knowing the utmost that is his attention to the use of gaseous or to be attained, and starting with the of liquid fuel, or of solid fuel reduced to sults that he obtains with the maximum, made continuous and uniform, and the consumption may not have been reduced, ing public will have high speed, and at

large expenditure of power. I anticipate, from the application of thermal science to practical engineering, that great results are before us in those heat motors, such as the gas-engine, where the heat is developed in the engine itself. Passing away from heat motors, and considering heat as applied to metallurgy, from the time of the hot blast to the regenerative furnace, it is due to the application of science by the engineer that the economy of the hot blast was originated, and that it has been developed by the labors of Lowthian Bell, Cowper and Cochrane. Equally due to this application are the results obtained in the regenerative furnace, in the dust furnace of Crampton, and in the employment of liquid fuel, and also in operations connected with the rarer metals, the oxygen furnace and the atmospheric gas furnace, and, in its incipient stage, the electrical furnace. To a right knowledge of the laws of heat, and to their application by the engineer, must be attributed the success that has attended the air-refrigerating machines, by the aid of which fresh meat is at the end of a long voyage delivered in a perfect condition; and to this application we owe the economic distillation of sea water by repeated ebullitions and condensations at successively decreasing temperatures, thus converting the brine that caused the Ancient Mariner to exclaim, "Water, water everywhere, nor any drop to drink," into the purest of potable waters, and thereby rendering the sailor independent of fresh-water stowage.

Sir Frederick Bramwell then proceeded to refer to the application, by the engineer, of electrical science, and to several other of the subjects dealt with in Section A. He then treated of the relations of mechanical science to the other sections, and concluded with these

words:

I trust I have now established the proposition with which I set out, viz., that not only in Section G, the section of mechanical science, but it is emphatically the section of all others that applies in engineering to the uses of man the several sciences appertaining to the other sections; an application most important in the progress of the world, and an application not to be lightly regarded, even by the strictest votaries of pure and inventions, I should set myself a Vol. XXXI.—No. 5—28

science, for it would be vain to hope that pure science would continue to be pursued if from time to time its discoveries were not brought into practical use.

Under ordinary circumstances I should have closed my address at this point, but there is a subject which at this, the first meeting of Section G after the meeting at Southport, must be touched upon. It is one of so sad a character that I have avoided all allusion to it until the very last moment, but now I am compelled to

grapple with it.

In the course of this address I have had occasion to mention several names of eminent men, many of them happily still with us, some of them passed away; but I doubt not you have been struck by the absence of one name, which of all others demands mention when considering physical science, and still more does it come vividly before us when considering the application of science to industrial purposes. I am sure I need not tell you this name, which I can hardly trust myself to speak, is that of our dear friend William Siemens, whose contributions to science, and whose ability in the application of science, have for years enriched the transactions of this section, and of Sections A and B, for in him were combined the mechanic, the physicist, and the chemist.

But a brief year has elapsed since he quitted the presidential chair of the Association, and, with us at Southport, was taking his accustomed part in the work of this and of other sections, apparently in good health, and with a reasonable prospect of being further useful to science for many valuable years to come. But it was not to be; he is lost to us, and in losing him we are deprived of a man whose electrical work has been second to none, whose thermic work has been second to none, and whose enlarged views justified him in embarking in scientific speculations of the grandest and most profound character. Whether or not his theory of the conservation of the energy of the sun shall prove to be correct, it cannot be denied that it was a bold and original conception, and one thoroughly well reasoned out from first

I feel that were I to attempt anything like the barest summary of his discoveries

task which could not have been fulfilled had I devoted the whole of the time I had at my command to the purpose. I the subject of my address, but I felt not trust myself to attempt it. There is no need for me to dwell further upon this most painful topic. He was known to you all, he was honored and loved by you all, and by every member of this As- you in this mournful strain. over which he had so ably presided; dear friend within the narrowest limits, land of his adoption; of the Continent, "out of the fullness of the heart the his birthplace; and of Canada, and of mouth speaketh."

the United States, whose populations are always ready to appreciate scientific talent and resulting industrial progress. had, indeed, thought of making his work It is not too much to say that few more gifted men have ever lived, and that that his loss was so recent that I could with all his ability and talent he combined a simplicity, a modesty, and an affectionate disposition that endeared him

I am sorry to conclude my address to sociation he had so faithfully served, and deavored to confine my allusions to our and he enjoyed the respect and esteem but if I have overstepped these I trust of the best intelligence of England, the you will forgive me, remembering that

LAKE MŒRIS AND THE PYRAMIDS.*

BY COPE WHITEHOUSE.

Contributed to Van Nostrand's Engineering Magazine.

In 1881, during the York meeting of the British Association, a paper was read under the title of The Topography of the Pyramids and their connection with Lake Mæris, the Bahr Jousuf, Labyrinth and Sphinx. It was shown that if the accounts of the ancient historians were treated as the honest efforts of intelligent men to describe what they had seen and heard there was no difficulty in blending their facts into a harmonious whole. The result, however, was so stupendous in its area of operations, the amount of human labor, the boldness and originality of the engineer, the wisdom of the government and the patience of the nation, that it could not be readily grasped, even by minds accustomed to the greatest works of centralized power. It was far easier to deny than to comprehend it. apparent contradictions in every great advance in knowledge. Light without smoke or heat has recently been obtained by electricity. The corridor of an Egyptian

sepulcher, lined with colored bas reliefs carved on fine-grained limestone after these blocks had been placed in position, had, for thousands of years, proved to the world by an ocular evidence which none could deny, that light could be separated from all that tended to impair health or injure works of art by imperfect combustion.

Ancient authors had agreed in describing a reservoir of Nile water, formed artificially, fifty miles to the south of Memphis (Cairo), and twenty to the west of the Nile Valley, with 450 miles of indented sea-coast, containing islands, teeming with 22 sorts of fish, fed by a canal with double mouth, filled each year from high Nile. The water, stored by dams or levees, which it cost \$70,000 annually to open and replace, was allowed to flow over the fields at low Nile for irrigation, or carried by tortuous, secret, subterranean channels into the local reservoirs of distant towns. "Meris," they said, whether meri the beloved, or Mer-uer the great sea (cf. mare Lat. mer Fr.) was the grandest triumph of man over nature accomplished in all the long period of Egyptian history marked by rock-hewn temple, obelisk, or colossus, and throughout the length of the river from the Soudan to the Medi-

^{*} This paper was withdrawn from the regular programme of Section E. of the American Association for the Advancement of Science, because it required lantern slides, and was read in the Academy of Music, Philadelphia, September 10th, and repeated (by request) in the Theatre of the Union League Club, September 12, 1884. The subject was presented to the New York Academy of Sciences, and discussed March 24, (see Critic, April 5th), and to the American Society of Civil Engineers, Buffalo, July 12. (See Reports in Engineering and other Journals). gineering and other Journals).

the upper plateau of the Fayoum, which sober history. show that a pond or pool covering about and used to irrigate that province, and M. Linant de Bellefonds had, it was said, rendered the world a service in exposing the errors and absurd exaggerations of Herodotus, Strabo, Diodorus and Pliny, allowed to pass uncorrected, or repeated, by Ptolemy, Stephen and the geographers of Alexandria and Constantinople. The Bahr Jousuf was shorn of its antiquity and reduced to a work of Saladin (Encyc. Brit.). The Labyrinth became, under the exploration of Dr. Lepsius, a pile of mud bricks of no importance, with the scant remains of a small temple. The Sphinx nevertheless continued to smile impassively and offered itself as an impenetrable riddle to philologist and historian, astronomer and engineer.

Three years ago, therefore, if each of the factors of this whole was closely examined, its importance and character defined by the latest researches, and the accepted conclusions of recognized experts substituted for the terms used by a Strabo or a Pliny, the splendid fabric, reared high above modern thought and modern attainment, seemed to have been a distorted reflection in the mirror of tradition, seen by men who lent a credulous eye and eagerly transmitted fables founded upon truth, but on so scant a measure of it, that a tenth or a hundredth became a standard division by which to reduce their dimensions to actual fact.

As the objections, however, to the ancient authors were successively examined it became evident that no serious impression had been made upon their credibility. The acuteness of Voltaire and the geology of Linant Pacha were equally at fault. Bunsen, bewildered by the personal assurances of Dr. Lepsius, lost himself in a Labyrinth which was pure fiction. turies before the Crusades, the Canal of Joseph was a familiar word in Arab legend, and a measure of human enterprise in irrigation works in the Valley of the Euphrates. The map of Egypt in 1881 was a blank, where a deep dry southern basin has since been found. In 1882 and

"But," said the modern 1883, accordingly, researches had been Egyptologists with absolute accord, "no made which gave to Lake Moris all the such Mœris ever existed." There are, it attributes ascribed to it, in papyrus and was explained, the remains of dykes on on parchment, in picture, legend, and

It followed as a direct consequence from 65 square miles was at one time formed the rehabilitation of Lake Mceris that other assertions were restored to importance. If there was a lake 300 feet deep, there was also an island "as near as may be in the middle, with two pyramidal summits, 600 feet in height from the bottom of the lake, and 300 feet from the surface of the water" (Herodotus). The king who made the lake had "left a place" and constructed a tomb together with two pyramids. The piles of stone by which the upper half of this mass of rock was revetted, or into which it had been quarried and shaped, served by their height to show to those who sounded the shallow eastern plateau that it sank into a deep erosion (fossa grandis, Pliny) under the steep shores of horizontal limestone which bounded it on the west. On the first publication of these discoveries in Paris, in the Revue Archéologique (Juin, 1882) and in London, in the Proceedings of the Society for Biblical Archæology (June 1882) sections across the Nile Valley were given. One of these has been reproduced in the Century (October 1884). These show that the popular conception of Egypt above the Delta as a plain is entirely erroneous. The ancients invariably spoke of the two sides of the Valley as the Arabian (eastern) and Libyan (western) mountains. These steep cliffs of 400 to 800 feet are not the result of any upheaval. The dead level of the Libyan Desert is the last stratum of a cretaceous deposit, through which the waters of the Abyssinian highlands and Equatorial Africa have cut their way. The Nilenow flows along the eastern shore of the cañon, and fills the lower level of it when high. To the west there are old channels, deeply scored by waterfalls in beds now dry, which are as much as 300 feet below the river and 200 feet below the sea. Everywhere scattered throughout this Libyan Desert are hills, pyramidal in form, with the axis in the line of erosion, with their bases sometimes 200 feet below the Mediterranean, but often rising as much as 800 feet above the valley of the Nile.

In the Wadi Reian the southwestern

their raison detre. It has been insisted coated and carried to a point, it would is only entertained by those who find to the west. Opposite to Gizeh, on the mysterious significance in its corridor east bank of the Nile are immense subterand coffer or sarcophagus. There is one ranean quarries, about 100 feet above the factor which had necessarily been over- plain. It was a natural inference that looked, all the pyramids are now seen to the stone of the Pyramids had been taken be (or to have been) either in, at, or near from these quarries. But it is evident that Lake Moeris and on the terrace above the this cannot have been the case. Apart high-level canals and aqueducts which entirely from the obvious absurdity of in the lake) are lower than the level of the lay at hand and which was good enough hills formed by erosion before the Nile enough to use in every other pyramid on had cut its way at its present level be the west bank, the stones now visible on

basin of Lake Mœris, there is a hill, never the African side on a barren stony mounbefore visited, known as the Haram. This tain," but Strabo, with an accuracy in word is applied exclusively to Pyramids which he had been preceded by Herodoby the Arabs. This hill is not a pyramid, tus, described them as in the brow of a but, like the island in the present lake, it hill, and not on its summit. This hill is justifies the ancient authors by affording over 150 feet above the plain. It rises a proof that "a place might be left" (by within Cheops a certain height, not less erosion) where a structure 600 feet high than 40 feet above the socket stones could be formed with a small amount of which have been regarded as the base of labor to serve as a monument of the immense natural wealth added to Egypt by greater height at its western summit and the construction of its vast storage reser- sinks again abruptly to nearly the level voir. If the Pyramids are to be treated of the Nile. North and south it is boundas a class it is evident that a common ed by ravines, so that if the Nile rose but factor must be found for them. It is a few feet higher, the hill of the Gizeh difficult to assign them definite attributes. plateau with its pyramids would become Prof. Perrot has, with great clearness an island. If a horizontal plane be passed shown that neither shape, dimensions, through the summit or even through material nor purpose seem to have been the apex, supposing that the sides were that the first of Gizeh, commonly called not be as high as Abu-Roash, 5 miles Cheops is an ideal pyramid and that to the north, the Mokattam, 8 miles to the others are imitations. This opinion the east, or the Kom el-Kashab, 9 miles were the conduits of its precious water. sending to the opposite side of a swollen The Pyramids in the Nile Valley (like those stream, 8 miles wide, for material which desert and are parts of islands or isolated for every purpose, and deemed quite good tween the commanding heights of Abu- the exterior of Cheops could not have Roash, crowned with a low pyramidal been quarried in the interior of a hill. structure containing chambers in the live Many of these blocks are deeply pitted or rock similar to Cheops, and the Mokattam worn by water. They show marks of with the citadel of Cairo, its extraordi- exposure to a disintegrating agent infinnary well and legends. The pyramids itely more powerful than the feeble action in Moeris were 600 feet high and yet of sun or wind with an occasional shower. natural hills. Medoum, the most southerly They are parts of the crust of a limestone of the Pyramids is, like Abu-Roash the hill, roughly broken perpendicularly, remost northerly, only a hill, squared into taining their natural horizontal surfaces shape and protected by walls of hewn as each layer could be pried off any of stone. Its chambers are far above the the exposed edges of the strata of rock, valley and within the stone casing. They laid bare and worn by the waters at their are, nevertheless, like every other cham- old level. It is therefore not a question ber found in or under every other pyra-mid except Cheops, wholly in the natural an absolute demonstration that these rock. The two pyramids of Gizeh cannot twin masses of coarse and worthless limebe dissociated. They are termed the stone, broken into convenient blocks and twins, and they have borne a fraternal piled without regard to any consideration relation from their first appearance in except stability and the angular form history. "They are," said Pliny, "on which would protect the adjacent terrace

from hot winds, laden with sand, could, with due regard to the ordinary operations of the human mind, the geological conditions of the rock, the engineering methods of the ancient world and similar structures still standing, have been formed out of natural hills, each block moved but a short distance, usually downwards, into chambers quarried in the hill itself, until a solid mass was made as the quarrymen "backstoped" upwards through the hill. They could then return over the outside, using the crust as a revetment and making a Pyramid which only differed from Medoum by the increased labor due to the frail character of the original hill, honeycombed with sepulchral chambers, temples or quarries. All tradition confirms this. built the Pyramids," said Surid, "to provide against the dreadful consequences of the Deluge which is to overwhelm the earth." But it was Meeris—the great seaof which, the two Pyramids in the lake, 600 feet high, were also monuments, which saved the Delta from the dread scourge of the annual flood. Hermes "brought the people from the mountains where they had retired for fear of the waters, and taught them to cultivate the plains." In these traditions as well as in the statement of Herodotus that these pyramids were built "from above," were completed "outwards," by a king who shut down the (rock-hewn) temples," at an uncertain date, for "all the authors do not make it clear who built them" (Pliny), and the silence of the Egyptian records, geographical, historical and poetical, led the author of this paper to affirm as a probable conclusion from well-established facts, in accordance with the principles of sound reasoning, that the huge piles at Gizeh are the results of a creditable effort to convert an unsightly and dangerous hill into a solid mass with some further purpose which modern science has not fully grasped.

The various steps in this argument were illustrated and proved by photographs of papyri, ancient and modern maps, sections of the Nile Valley from personal and original surveys, sketches and photographs of natural hills of pyramidal form in Egypt and Nubia, with midal pile of rough-hewn stones. examples of denudation of horizontal The Society of Civil Engineers at its beds elsewhere, the quarries of Turra, meeting June 12, 1884. (see the Amerithe natural strata in the head of the can Engineer) agreed that the stones

Sphinx and under the Pyramids of Gizeh, and the sides of the Kom el-Kashab, Abu-Roash and the Mokattam. partially completed façades of Petra The limewere begun at the top. stone quarries of the Nile were worked in "stopes" or ledges, in subterranean chambers and passages. Evidence was also furnished that these facts and suggestions had been put before the scientific world in definite form, and had elicited the approval of competent judges. The survey of the Desert to the west of the Pyramids was inserted by Prof. Perrot and M. Chipiez in their history of Egyptian Art (Eng. Ed., 1882). London Academy described with approval how it had been "conceived that the Gizeh plateau was once a range of hills, weathered into fantastic shapes, to which horizontal strata gave an artificial appearance and pyramidal summits," and "the inferior material was cut into blocks, lowered from above and pushed into place to build the Pyramids." The Wadi Reian, eroded to a depth of two hundred feet below the Mediterranean, and the hills in the Wadi Fadhi have been placed upon the map of the British War Office. The Geographical Society of Cairo, 1883, indorsed the surveys of 1882 and 1883 as a new and important contribution to the cartography of the Libvan Desert. The Dutch Academy of Sciences (1884) republished the geographical Papyrus of Boulag with a map to show that this document had been, hitherto, wrongly interpreted, but the Abbé Amelineau had already demonstrated this at length in the Revue des Questions Historiques, (Oct., 1883). The Report of the New York Academy of Sciences (Critic, April 5th, 1884), refers more particularly to the proof that "horizontal limestone once filled the Nile Valley to the height of nearly a thousand feet, and several hundred feet above the tops of the Pyramids," and that "the tombs under the Pyramids appear to be older than the structures above," while the granite blocks (from Assouan) and coffer, being too large to have been brought through the entrance and passage, may have been put into the hill before it was reconstructed into a pyra-

by concentric and successive layers. andria-Cairo-Suez Canal. At the meeting of the British Assoas conclusive of the former extent of Lake around the nameless sarcophagus of an Mœris, while the complete absence of ear-unknown personage.

might have been actually quarried in a ly reference to the Pyramids confirms the hill and lowered into their present position conjecture that they are comparatively so that the amount of labor would have modern, and did not exist in the time of been exceedingly small in comparison Rameses-Sesostris. The reopening of Lake with that required to construct the piles Mæris would greatly facilitate an Alex-

It is obvious that unless these facts ciation for the Adv. of Science in Montreal are contradicted, it is legitimate to infer (Aug. 27, 1884) reported in the Oct. No. of that the situation of the Pyramids is an the Proceedings of the Royal Geog. Soc., important factor in the question of their the accuracy of the ancient historians purpose. The problem of their construcwas shown and the use of technical tion is to find the easiest and most natwords explained. The restoration of ural method. Why hills at, in or near the South-Western basin (see Satur- Lake Moeris should have been revetted, day Review, Jan. 25th; 1883; The Cen- or reconstructed, into square or rectantury, October, 1884) was advocated. gular masses with sloping sides may never the Ptolemaic maps were justified by the be explained, but, even in that event, a levels run by theodolite and spirit level stigma is removed from the history of the as well as aneroid barometer, alone or human race, and especially from its enwith the aid of Messrs. Ellis, Gasperoni, gineers, by showing that these are not Petrie and others. Wide fields of archæo- piles of stone, quarried on the right bank logical research were indicated and a of the Nile and transported to the left hieroglyphic inscription from Edfou cited bank, only to serve as a tumulus above or

THE MANCHESTER SHIP CANAL SCHEME.

By H. S. S. SMITH, C. E., Princeton College.

Written for Van Nostrand's Magazine.

certain sense, unfortunate that the pres denies that the proposal, if practicable, mental to existing interests.

The proposition to make Manchester a | Manchester and began active operations sea-port is not a new one. Like every by appointing Mr. Hamilton Fulton and great undertaking, it has been preceded Mr. E. Leader Williams engineers to by various plans to accomplish the same prepare reports and estimates of the propurpose. Forty years ago Mr. Palmer posed undertaking. Each of these enagitated the question, and since then Mr. gineers made a report to Mr. Abernethy, Bateman and Mr. Fulton have been earn-the consulting engineer, the two plans est in their endeavors to have the idea being so radically different that it was reach actual achievement. It is, in a impossible to combine them into one. Mr. Fulton's proposal was "to straightent discussion of the subject has thus far en, deepen and widen the Irwell and been barren of material results, for no one Mersey between Trafford Bridge, Salford and Liverpool so as to afford a depth of would be of great benefit to a large and 22 feet at low water of spring tides." active manufacturing center. But the As this plan would require a rock-cutting grounds on which permission has been 40 feet deep and 10 miles long, and denied by Parliament are evident and would place the docks at Manchester 92 reasonable, and it remains to be seen feet below the present surface of the whether or not the same object can be ground, the report was not adopted by reached in a way that will not be detri- Mr. Abernethy. The report made by Mr. Williams was essentially different, The present agitation of the question and was the basis of the proposal that took a definite form in June, 1882, when was laid before Parliament. He proa provisional committee was formed in posed to excavate a ship canal in the

21.25 miles. locks, worked by hydraulic power, with tees investigated the matter as before. steam reserve in case of drought. From and the result was that the Lords passed Runcorn the channel in the estuary was the bill, while the Commons Committee to be straightened and deepened by refused to do so. It is said that \$1,500,dredging and by the erection of training 000 have already been spent in promottinct parts to the work, the canal portion reason to believe that the real cause of from Manchester to Runcorn, and the the defeat of the bill was the engineering estuary portion from Runcorn to the evidence produced by the opposition, deep water just above Liverpool. Mr. it will be interesting to study the cir-Williams made detailed plans and esti- cumstances of the case, and see what the mates for the former, but it would ap- conditions really were. pear that no estimates were made for the portion of the work below Runcorn.

the manufacturing interests generally. miles below Manchester. From this of Liverpool, and the harbor boards and whose shape is that of an irregular cresneeded, and would be beneficial to a corn to nearly northerly at Dingle Point. large volume of trade, was proved bebe laid before them. The Committee of in width.

valleys of the Irwell and Mersey from technicalities to contend with, but the Manchester to Runcorn, a distance of opposition produced strong engineering This canal was to have arguments against the scheme. Commit-There would thus be two dis- ing and opposing the bill. As there is

To understand the plans it will first be necessary to give a brief description of A bill was drawn and brought before the existing waterway from Manchester Parliament, but, as the standing orders to the open sea. The city is situated on had not been fully complied with, it was the Irwell, a small stream having a depth admitted only by special permission, and of only four feet under favorable circumafter considerable debate. The support-stances. Flowing westward from Maners of the bill were the merchants and chester, it joins the Mersey after a windlocal boards of Manchester, the cham- ing course of about 6 miles. The direcbers of commerce of many places that tion and character of the stream remain would be benefited by the works, and practically unchanged to Warrington, 15 The opponents were the railway com- place to Runcorn, 6 miles below, the panies having lines between Liverpool limit of draught is 9 feet. At Runcorn and Manchester, the various local boards the river meets the estuary, a basin navigation companies having interests in cent, the direction of the general axis the river Mersey. That the canal was changing from nearly westerly at Run-

The length of the basin is about 12 yound doubt. But the lack of definite miles, and the area is 27.2 square miles. plans and estimates for the estuary part At low water about 20 square miles of of the work told heavily against the pro- sand banks are uncovered, and the chanmoters of the enterprise. The committee nels between have an effective depth of of the House of Commons, after a pa- but 12 feet. The banks and channels tient and thorough investigation, lasting are subject to continual and rapid change thirty-seven days, passed all of the bill under the action of the tide. The outlet excepting that portion referring to the is a channel extending from Dingle work in the estuary, reserving decision Point to Rock Lighthouse, about 5.5 on it until full plans and estimates should miles in length, and from 0.6 to 1.0 mile This channel is lined with Lords, after a brief and superficial in-quiry, decided that it was not expedient the east and Birkenhead on the West; to proceed with the subject during that and, although the mid-channel at low water has a depth of 70 feet, the deposi-The time intervening between this and tion of silt in the dock slips is so steady the next session of Parliament was that constant dredging is necessary to spent by the promoters in altering the preserve their usefulness. Rock Lightlocation and plans, and perfecting the house is at the head of Liverpool Bay. estimates of the canal part, and in de- The two parts of the shore of the bay signing the plans for the channel in the are nearly at right angles to one another, estuary. When the bill came again bethe eastern shore inclining slightly west fore Parliament there were no formal of the direction of the channel from

Dingle Point to Rock Lighthouse, and tion of the silt brought in by the flood reaches to Formby Point, while the southern shore extends in a direction a little south of west to Hoylake Lights, near the mouth of the river Dee. From Rock Lighthouse to the open sea the distance is about 11 miles. The whole of the bay is occupied by banks and shoals, about 34 square miles being entirely uncovered at low water. There are two main channels across the bay. The principal one, Crosby Channel, is a continuation of the Mersey from Rock Lighthouse to Crosby Light, and then bar at the Bar Lightship. A less imwestward from Rock Lighthouse along to the bar. face of the bay there is a bar that gives, the buoying of the channels is a matter only 12 feet at low water. channels and bar are constantly chang- uniform, the amount deposited by high ing under the wear of the tides, and, al- water and the amount excavated by the though the changes are not particularly low-water currents being just about equal rapid, they are sufficient to demand con- day after day and year after year. The stant watching on the part of the harbor action of the tide in Liverpool Bay is to authorities.

rying capacity. In the channel between be meddled with. Rock Lighthouse and Dingle Point the as 5.5 miles an hour. broad basin between Dingle Point and from any special difficulty. place. is consequently level. From this condition of things there re- lower levels.

tide on the higher banks in the basin. As these banks are, in many places, only five feet lower than high-water level, by the time the ebb currents begin to run with any decided velocity they have become completely uncovered, and the silt deposited on them by the flood is above the reach of any erosive action. But the velocity of the water in the low water channel is sufficient to enable it to carry a large amount of silt, and the banks of these channels are being continually undermined and broken down by the wearturns to the north-west and crosses the ing action of the water in a way quite similar to that shown in the caving banks portant one is the Rock Channel running of the Mississippi. This action produces constant change in the position of the the Southern shore of the bay nearly to channels, a change so prominent that Hoylake Lights, and then turning north monthly surveys of the estuary are neces-Across the entire seaward sary in the interests of navigation, and when in its best condition, a depth of of constant care. Although the changes The banks, are constant the results are remarkably change the banks and channels to some ex-While the character of the bottom tent, but not rapidly, while its principal efand the configuration of the shores ren- fect is in keeping the bar scoured down der the channels and harbor far from to a depth that permits navigation. The convenient and safe for shipping, the bar is the most troublesome part of the height and violence of the tide add much entrance to the Mersey, and while the to the complexity of the situation. The depth at low water is seldom more than total rise of an ordinary tide is 30 feet. 12 feet, and thus prevents continuous The water, coming from the west, and passages by ocean steamers, it is considconfined between limits that are contin-ered by the harbor authorities at Liverually narrowing, develops a high silt-car- pool as better than none, and must not

The plans for the canal from Runcorn velocity of the tidal current is as high to Manchester showed an engineering Reaching the project of large dimensions, but free agle Point and from any special difficulty. In section, Runcorn the velocity and, consequently, the canal would have a breadth of 120 the silt-carrying power are much dimin- feet at the bottom, side slopes of 1.5 to ished, and a rapid deposition of silt takes | 1 in earth, but varied in rock, and a This action is rendered more depth of 26 feet. The locks would all complete by the fact that for more than be similar in plan, but with different half the length of the estuary high water lifts. The plan shows three separate occurs at the same time, and the surface basins side by side, 550 by 60 feet, 300 The surface re- by 40 feet, and 100 by 20 feet, respectmains level for 2 hours and 40 minutes, ively. Sluices were to be built in conand although it falls 13.5 feet in that nection with each set of locks to pass time the current is scarcely perceptible, the overflow and storm waters into the

sults a rapid and almost complete deposi- Starting from the Mersey at Astmoor

Marsh, about a mile above Runcorn, the canal would keep a straight westerly course for 9.75 miles. At 0.75 miles set of locks, providing a lift of 17 feet at low tide, while high water would flow 5 feet above the intended water level. It was intended that this five feet of water should be used to scour the canal and the channel in the estuary at low water. At 4.5 miles, near Warrington, the London and Northwestern, and the Birkenhead, Lancashire and Cheshire Railways are met. In order that these might pass at a sufficient height it would be necessary to raise the grades at crossing some 43 feet, and the approaches would be about a mile long on each side and have gradients of 1 in 132. To accommodate the trade at Warrington, it was determined to build there a dock 20 acres in extent, with lines of track running from it to the railways. The dock would be connected with the Mersey by a small lock suitable for river craft. At 7 miles the Warrington and Stockport branch of the London and Northwestern Railway would be passed, the plan of passing being the same as for all the other railways. At 7.25 miles there would be the Latchford locks, with a lift of 15.5 feet. The canal would then folestimated by the engineers that this porlow the valley, but would be independent tion of the work would cost \$25,800,000, of the river, crossing the bed of the river and could be completed in four years. several times. Below the limit of tidal well and Mersey into the canal, and to fill the bed of the stream thus abanpoint about 4 miles above Dingle Point. der the Liverpool and Stockport Railway, would gradually increase from 300 feet to and at 14.5 miles, under the Liverpool 1,000 feet in breadth, and would be and Manchester Railway. In each of dredged to a depth of 26 feet at low these cases it would be necessary to water. It was found that there was good raise the grades 40 feet, and to make the foundation, either of rock or gravel, at a approaches in the same manner as for reasonable depth on which these walls the other lines. At 14.75 miles there could be built. Materials for the walls would be the third set of locks, the Irlam would be easily obtained from the rock locks, having the same plan and sluices cuttings on the canal. The difficulty lay, as the others, but with a lift of 13.5 feet. not in the construction, but in the prob-The work just below these locks would be able effect of the proposed training walls heavy, but it would seem better to have on the tidal flow in the estuary, on the the railways cross the lower level. Con-tinuing to follow the valley with gentle ity of the basin. It was proposed by the curves the canal, at 17.25 miles, would promoters of the scheme, and the pic

These would be the same as those at Irlam. At 18.1 miles the canal would pass under the Barton aqueduct of the from Astmoor Marsh is placed the first Bridgewater Canal, built by Brindley in 1760. It would be necessary to make some arrangements to get the ships past this, as the headway would be insuffi-It was proposed to build a new aqueduct, of which a part should be an iron trough balanced on a central pier and fitted with watertight gates, so that it could be swung around in the manner of a drawbridge. From this place to Manchester the canal would follow the valley of the Irwell, and finally reach the proposed site of the docks, 21.25 miles from the beginning of this portion of It was proposed to take the the work. Manchester Racecourse grounds for the docks of the ship canal. The surface would be 6 to 8 feet above the water surface, and by excavating a water space of 70 acres to the depth of 26 feet, it was expected to give accommodation to 1,260,-000 tons of shipping per year. By widening and deepening the Irwell above the docks this could be increased to a capacity of 1,800,000 tons with the additional advantage of improving the connection between the ship canal and the smaller canals centering at Manchester. It was

The construction of the works in the flow at Woolton Weir the river would be estuary presented a problem containing diverted, but above that point the propomany uncertainties. The general plan sition was to turn all the water of the Ir- was to construct training walls from the doned with earth from the canal cuttings. and thus cause the low water channel to At 13.25 miles the canal would pass un- keep a definite position. This channel reach the last set of locks at Barton, osition was sanctioned by the surveyor

of the port, to make the walls of such a ume of water transported as tidal flow height that they would "never remain would be correspondingly lessened, and wholly uncovered during the whole of any neap tide." It was argued that by This reduction in velocity means a still so doing the tidal capacity of the basin greater reduction in silt-carrying capacwould not be decreased, but, on the con- ity, because this latter varies as the trary, would be increased, by the deepening of the channel that would result of volume, velocity and silt-carrying cafrom the constant scouring. It was ar- pacity would be effective, not only in the gued that the increased velocity that estuary between Dingle Point would result would increase the silt-car- Runcorn, but also in the channel berying power, and that the proposed im- tween Dingle Point and Rock Lightprovements would not only serve the house, and over the whole extent of purpose for which they were made, but Liverpool Bay between the lighthouse would result in a permanent improve and the bar. The result would evidently ment of the channel from Dingle Point be that the depth of the channel oppoto and across the bar. While this reasoning seemed very just on the face of it, it was proved to be false reasoning on depth of water on the bar would be deinsufficient grounds, and it was here that creased. the opposition made a successful stand. The Mersey Dock and Harbor Board, opposed to the construction of the canal because the trade at the Liverpool docks would be much decreased thereby, engaged Mr. J. B. Eads to investigate the the proposed undertaking was one that subject of the tides in the estuary and bay, and to report on the probable effect of the construction of the proposed training walls on the tidal capacity of the estuary and on the channels in the bay. The results of his investigations on the tides, and the manner in which they carry and deposit sediment and keep the capacity of the basin uniform have been already given. Bearing the facts in mind, it will be comparatively easy to trace out the sequence of results that would follow from the construction of such walls as were proposed. The deposition of silt on the shoals in the estuary would, at first, be as before; but the wearing action of the low-water currents on their banks would be stopped by the training walls, and there would result an inequality between the gain and loss of silt in the shoals with a balance in favor of the Runcorn it would pass to the south, skirt This would soon raise the height of the shoals nearly to the level of high tide, and the capacity of the basin would be decreased by an amount river Dee. Although no detailed estinearly equal to this, for the increase of mate of this work has been made, it capacity coming from the increase of would appear that there would be no depth of the channel would be small in great difficulty in the way of such a plan. comparison with the volume occupied by flood tide. The tidal capacity of the ba- close acquaintance with the hydrography sin being thus decreased by the gradual of the place is necessary to warrant the

site Liverpool would be lessened by silting, and that even the present shallow These facts and their logical results were placed before the Parliamentary committees in a clear and forcible manner, and it is not strange that they refused to pass the bill.

It has been admitted on all sides that would be of very great benefit to a large and active manufacturing center, and because one plan has been proved to be not feasible is no reason for thinking that the object in view cannot be attained. There are still at least three ways of providing a deep water channel from Manchester to the sea. One of these would, at the same time, greatly benefit the communication between Liverpool and the sea, while the other two would have no influence at all on the existing waterways

below Dingle Point. The expedient suggested by Mr. Eads, in answer to questions put to him when before the committees, was to construct a ship canal similar to the one proposed, but extending all the way from Manchester to the sea. That is, instead of entering the estuary of the Mersey at the Cheshire shore of the estuary, and enter tidal waters somewhere between Rock Lighthouse and the mouth of the

While it must be acknowledged that a deposition of silt on the shoals, the vol- elaboration of a scheme for realizing the gineering standpoint.

the estuary.

that would have no prominent influence progress in connection with the complion the channels and bar of the bay, is cated tidal action. this: Starting from the proposed terminus of the canal proper at Runcorn, con-would be the difficulty of leaving the struct two training walls whose tops present docks and water fronts along the should ultimately be above high water of shores of the estuary far removed from spring tides, and place them at such a any navigable channel, and the formation distance apart that at any place the area between 10 and 20 square miles of new of the cross section between them occupied by the water that comes in at flood tide would be equal to the present area occupied by the flood on the same cross section; or, rather, so proportion them that the total volume between them occupied the formation of a deep-water channel by the water of flood tide would be equal from Manchester to the sea is not an imto the present tidal capacity of the estu-possibility, and will probably be an acthe low-water channel has a breadth of the century. 0.4 miles, while the remaining 3.1 miles are covered by shoals at low water. The breadth of an equivalent channel would be about 2.1 miles. Or, if these training walls were to be a uniform distance apart, this distance would be about 1.3 mile, in order to furnish the same tidal capacity as at present. At Dingle Point, or a little above, these walls should be made to join the shores on either side. Since boro during its thirty days. The size of Krathe depth and uniformity of a channel have a great influence on the velocity and the consequent silt-carrying capacity of a tidal current, it would seem that the condition of the channels below Dingle Point would be improved by such a change in the estuary.

The second scheme is of much greater magnitude. It would make an unimpeded deep-water channel all the way from Runcorn to the open sea, by the erection of high-tide training walls from Runcorn to Dingle Point, and from Rock channel between Liverpool and Birkenhead untouched. While this would dimthe estuary, it would keep all of the tidal Krakatoa lifts defiantly out of the sea.

desired end, a close scrutiny of the many action within definite boundaries, so that facts that have been elicited by the agitation of the question fails to show why formation of shoals. There would howeither of the following schemes would be ever, be the probability of decided diffi-impracticable when viewed from an en-culty in the matter of the deposition of Each of them silt at and near the mouth of the channel. would, however, seriously and completely There is no large body of water flowing interfere with the riparian rights along seaward to carry away the silt, as in the nearly the whole of the present shore of case of the Mississippi. It would be exceedingly difficult to predict what the depos-The first one to be mentioned, the less iting action would be, as it appears that expensive one of the two, and the one some kind of a geological change is in

With either of these schemes there land between the proposed channel and the present shores. Whether these would be sufficient to prevent the carrying out of the plan is a question that must be decided on the spot. In any case, however, Thus, opposite Ellesmere Docks complished undertaking before the end of

Rom a paper read before the Royal Institu-tion by Professor J. W. Judd, it appears that the Krakatoa cataclysm destroyed over 35,000 people, but as a volcanic outburst it was comparatively small to that of Tomboro in 1815. The Krakatoa was, however, more violent for the few hours it lasted than the Tomkatoa was formerly 331 square kilometers: of that 23 square kilometers have subsided, and 10½ square kilometers remain extant. But on the sonth and sonthwest side the island has been increased by a large ring of volcanic products, so that the size of New Krakatoa is now. according to the survey, $15\frac{1}{3}$ square kilometers. The size of Long Island was formerly 2.9 and is now 3.2 square kilometers. Verlaten Island has become much larger; it was formerly 3.7 and is now 11.8 square kilometers in size. Of the Poolsche Hoedje nothing remains. In the place where the fallen part of Krakatoa ouce stood there is now everywhere deep sea, generally 200, in some places even more than 300. meters deep. It is remarkable that in the midst Lighthouse to deep water, leaving the of this deep sea a rock has remained, which rises about 5 meters above its snrface. Close to this rock, which is certainly not larger than inish the tidal capacity of the bay and of the estuary it would keep all of the tidal representations. It is like a gigantic club, which

ON THE PRESERVATION OF IRON BRIDGES.

By E. PASCHEN.

From Abstracts of the Institution of Civil Engineers.

sity for the general adoption of some system, whereby the condition of existing iron bridges may be ascertained and recorded, and periodical inspections of all such structures be made in the future.

As regards the iron bridges erected in Germany, those upon the earliest constructed lines of railway, although not intended to carry the heavy class of locomotive now in use, were designed with such an ample margin of strength and constructed in so careful a manner as to be equal to the increased stress produced by the present type of engine; but with the progress of railway construction, investigation led to more familiarity with the direction and amount of strains upon bridge structure, and there ensued a desire, which seems to have become general, to economize the amount of metal to the utmost, basing the calculations upon the then existing conditions, and disregarding the possibility of the introduction of a heavier class of locomotive; so that, at the present time in many bridges, the metal, at the transit of every train, is subjected to strains in excess of that which is assumed to be permissible.

This applies more to small than large spans, as the amount of increased load, due to the use of heavier engines, is proportionally greater in the case of the former than of the latter. With the increase in the number and magnitude of bridges erected, a tendency to deterioration in the character of the work and ma-

terial employed ensued.

The author mentions the failure in some instances of the hinge ("Pendel") bed-plate, and advocates the use of the usual expansion roller frame only, and, after enumerating the evils arising from various causes, such as the removal of the overhead transverse ties in the case of deep girders (causing lateral distortion), insufficient riveting at the intersection of lattice bars, inattention to condition of paint, and the non-provision of a sufficient thickness of timber between the rail and

The author urges the growing neces-the necessity for the employment of competent inspectors during the progress of the work, both at the place of manufacture and erection.

> Reference is made to the Society of Architects at Berlin, which has directed its attention to the question, and proposes that the railway companies generally should institute a system of periodical inspections and reports as to the condition of their various iron bridges, and recommend that the observations should be divided into two classes, the first (general) to be made in respect of every bridge, and the second in special instances only.

> "The general observations (to be made every five years) to include—

> "1. Measurement of permanent deflec-

"2. Measurement of deflection caused

by loading (at rest).

"3. Enumeration of those portions of the structure and rivets which may have already been renewed.

"4. Careful examination of plates at junctions of bracing with booms, &c.

"5. Careful examination of paint and those places affected by rust.

"The special observations (to be made annually) to include—

"6. Deflection of the lower flange under a moving load.

"7. Distance apart of the top and bottom flanges.

"8. Length of the diagonals.

"9. Lateral distortion and vibration at the center of the girders.

"All observations upon the structure when repeated, to be, if possible, made by the same inspector."

In modification of the above the author suggests that the result of observations made by mere inspection should be kept separate from those obtained by loading, as the former could be made at any time at comparatively slight expense, and the most important of the defects discovered, whereas the latter would necessitate the the ironwork of the structure, points out presence of a sufficient number of en-

gines of the heaviest class, and for the by wind-pressure under the conditions time being, stop all traffic; he therefore proposes that subordinates should be first carefully instructed under the supervision of the chief inspector, and that afterwards it should be their duty frequently to examine the structures, a formal report from personal observation being made by him once in two years, and that the load-test should be employed only once in ten instead of five years.

The special observations, it is suggested, should include the effect of temperature upon the length of the girders, the amount of movement in the roller bedplate with trains moving in both directions, the comparative distances apart of the web-verticals, measured near the top and bottom flanges when the girder is the Werda Bridge, a double-line strucloaded, and the lateral deflection caused ture of six 67-feet spans.

of a loaded and unloaded girder.

The author recommends that a book should be kept for the entry of the inspectors' report, the information being under the following headings, viz., name, short description, and, where possible, the calculation of the strains, and a general sketch with details of the most important parts; weights of iron in the construction, total weight of superstructure; details as regards the history of the construction, name of maker, &c.; character of the materials, and results of experiments as to strength, amount of deflection under moving and fixed load, &c.

An example is given of an entry in the Bridge-Book, with a sketch referring to

THE EFFICIENCY OF FLUID IN VAPOR ENGINES.

BY H. L. GANTT, A. B., M. E., AND D. H. MAURY, JR., M. E.

Contributed to Van Nostrand's Engineering Magazine.

of fluid of different vapors was suggested by Prof. R. H. Thurston to the writers as a subject demanding investigation.*

This suggestion was the more gladly accepted as the writers had desired to investigate, and if possible, to make a practical test of, a vapor engine, which was at that time awakening some interest in engineering circles in New York City and elsewhere. Failing to obtain permission to test the engine in question, the writers were compelled to confine themselves to a purely theoretical discussion of the subject.

2. Rankine, Clausius and others have proved that the amount of heat transformed into work does not depend upon the fluid which is the conveyor of that heat, but simply upon the limits of temperature between which the fluid is worked. It follows that, theoretically, all fluids are equally efficient in transforming heat into work; it does not follow, however, that all fluids are equally valuable as the work-

I. The determination of the efficiency ing fluid of an engine, for there are other considerations beside efficiency to be taken into account in making choice of a working fluid. We have set ourselves the task of choosing the best working fluid from the following liquids: water, alcohol, ether, bisulphide of carbon and chloroform.

Case I.

3. This section is devoted to a discussion of Carnot's cycle, first in general, and then as applied to the vapors in question, with the object of showing that, while the efficiency of fluid is the same in each case, that of the engine may be different, and in general will be, since its efficiency will be less as the size of engine required to produce a given power is larger.

4. Carnot's cycle consists of an isothermal expansion, an adiabatic expansion, an isothermal compression, and an adiabatic compression up to the original tempera-

We shall suppose a certain amount of heat, L, to be worked in the cycle of Carnot, between the limits of temperature t, and t_o , by any fluid, and then by each of the fluids in question, and shall show that, while neither the work of expansion nor

^{*}The writers take this occasion to express their gratitude to Professor Thurston for his great kindness in placing at their disposal his valuable library, and for the many other favors shown them during the progress of their work.

that of compression in any case is equal to the corresponding quantity in any other case, their difference, the effective

work, is equal in all cases.

We suppose our fluid to be at the temperature t_1 , and that we have just so much of it as will be evaporated by the heat L₁. The evaporation accompanies the isothermal expansion represented by AB, Plate I., Fig. 1. The adiabatic expansion BC, then takes place until the temperature falls to t_2 ; the isothermal compression is shown by CD and the adiabatic compression by DA.

5. Rankine gives as the formula for the rates of expansion necessary to reduce the temperature of steam from t, to t, *

$$r = \frac{\tau_2}{\mathbf{L}_2} \left(\mathbf{J} \, \mathbf{D}_1 \, \log_{e} \, \frac{\tau_1}{\tau_2} + \frac{\mathbf{L}_1}{\tau_1} \right).$$

 $\tau_{,=}$ absolute initial temperature on the Fahrenheit scale.

 $\tau_{\rm a}$ =absolute final temperature on the Fahrenheit scale.

L = latent heat of evaporation of a cu. ft. of vapor at temperature t_1 , in foot pounds.

L₂=latent heat of evaporation of a cu. ft. of vapor at temperature t_2 .

D = weight in lbs. of cu. ft. of vapor at temperature t_1 .

J=mechanical equivalent of heat in foot pounds.

This formula may be made applicable to all vapors by the introduction of K, the specific heat of the liquid, as follows.

$$r = \frac{\tau_2}{L_2} \left(JD_{_1} K \log_{e} \frac{\tau_{_1}}{\tau_{_2}} + \frac{L_{_1}}{\tau_{_1}} \right) \quad . \tag{1}$$

The formula for the work done per stroke, in a steam engine, by a unit volume of vapor at temperature τ_1 as given by Rankine† is

$$\begin{split} \text{Work=JD}_{_{1}} \Big\{ \tau_{_{1}} - \tau_{_{2}} \Big(1 + \log_{e} \frac{\tau_{_{1}}}{\tau_{_{2}}} \Big) \Big\} + \\ + \frac{\tau_{_{1}} - \tau_{_{2}}}{\tau} \mathbf{L}_{_{1}} + r(p_{_{2}} - p_{_{3}}), \end{split}$$

which may be made applicable to all vapors by the introduction of the specific heat K of the liquid. It then becomes

Work=JKD₁
$$\left\{ \tau_1 - \tau_2 \left(1 + \log_e \frac{\tau_1}{\tau_1} \right) \right\} + \frac{\tau_1 - \tau_2}{\tau_1} L_1 + r \left(p_2 - p_3 \right) . \quad (2)$$

The pressures p_2 and p_3 are the tensions of the vapor at the temperatures t_2 and t_3 in pounds on the square foot; t_s being the temperature of the condenser, p_s is the

back pressure.

6. Equation (2) may be illustrated by the diagram, Plate I., Fig. 1. The ordinates represent pressures and the abscissas represent volumes. $AO = p_1$ the initial pressure. $CG = p_2$, the final pressure. HG and KO represent p_3 , the back press-Equation (2) is an expression for the work represented by ABCHK. If the final and back pressures become equal, equation (2) becomes

$$W = JKD_{1} \left\{ \tau_{1} - \tau_{2} \left(1 + \log_{e} \frac{\tau_{1}}{\tau_{2}} \right) \right\} + \frac{\tau_{1} - \tau_{2}}{\tau_{1}} L_{1} . \quad (3)$$

and the diagram representing the work is ABCE.

If an amount of heat, L, is added to a fluid at the temperature τ_1 , and then worked in the cycle of Carnot between the temperatures τ_1 and τ_2 the amount of

heat changed into work is $\frac{\tau_1 - \tau_2}{\tau_1}$ L, as

shown by Rankine, Clausius, and other writers. From this it follows that the work represented by ABCD is equal to $\frac{\tau_1 - \tau_2}{\tau}$ L, and therefore the work of adiabatic compression in the cycle of Carnot is

$$\text{JKD}_{1} \left\{ \tau_{1} - \tau_{2} \left(1 + \log_{e} \frac{\tau_{1}}{\tau_{2}} \right) \right\}$$

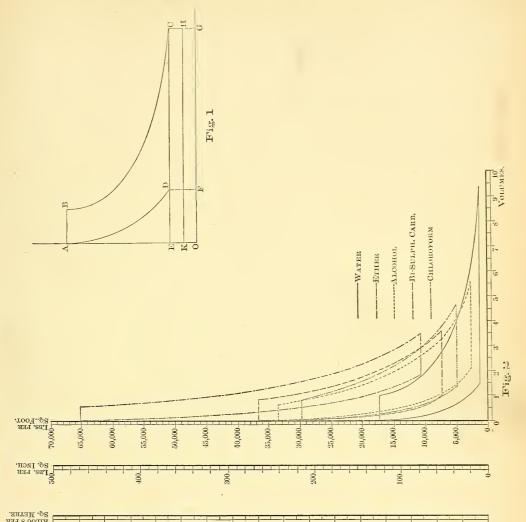
The total work of compression v^2 , being the volume at the end of adiabatic expansion is

$$p_2 v_2 + \text{JKD}_1 \left\{ \tau_1 - \tau_2 \left(1 + \log_{e} \frac{\tau_1}{\tau_2} \right) \right\}.$$

If the amount of vapor produced by the heat L, is not a unit volume, but is represented by v_1 , the work of expansion in Carnot's cycle becomes

$$\begin{split} \mathbf{W} &= \mathbf{J} \mathbf{K} \mathbf{D}_{1} v_{1} \bigg\{ \boldsymbol{\tau}_{1} - \boldsymbol{\tau}_{2} \bigg(\mathbf{1} + \log \boldsymbol{\cdot}_{\theta} \, \frac{\boldsymbol{\tau}_{1}}{\boldsymbol{\tau}^{2}} \bigg) \bigg\} + \\ &+ \frac{\boldsymbol{\tau}_{1} - \boldsymbol{\tau}_{2}}{\boldsymbol{\tau}_{1}} \mathbf{L}_{1} + \boldsymbol{v}_{2} \, \boldsymbol{p}_{2}, \quad . \quad (4) \end{split}$$

^{*} Steam Engine, p. 388. † Steam Engine, p. 388.



which is represented by ABCGO; the total work of compression is

JKD₁ v_1 $\left\{\tau_1 - \tau_2 \left(1 + \log_{-e} \frac{\tau_1}{\tau_2}\right)\right\} + v_2 p_2$, $v_2 p_2$ being represented by CGOE, and
JKD₁ v_1 $\left\{\tau_1 - \tau_2 \left(1 + \log_{-e} \frac{\tau_1}{\tau_1}\right)\right\}$, by ADE.

The principal data a are reduced to Brigiven in both British in a table at the end.

It is necessary to required for substituting and (3), which data a

The effective work is $\frac{\tau_1 - \tau_2}{\tau_1} \mathbf{L}_1$.

7. As all the data available for the solution of this and the following cases are found in French and German works, and

are consequently expressed in the metric system, we have adopted that system. The principal data and results however, are reduced to British units, and are given in both British and metric systems in a table at the end.

It is necessary to find the quantities required for substitution in equations (1) and (3), which data are:

J=424 kilogrammeters.

 τ_1 and τ_2 , initial and final absolute temperatures on the Centigrade scale.

L, and L, latent heats of evaporation, in kilogrammeters, of one cu. me-

ter of saturated vapor at temperatures τ_1 and τ_2 respectively.

D, and D = weights in kilograms of one cubic meter of saturated vapor at temperatures τ , and τ , respectively.

> = t ensions, in kilograms on the square meter, of the vapors at the temperatures τ_1 and τ_2 .

K=mean specific heat of the liquid between the temperatures τ_1 and τ_2 .

8. The initial and final temperatures chosen are

$$t_1 = 172^{\circ} \text{ C. and } t_2 = 90^{\circ} \text{ C.},$$
 or $T_1 = 445^{\circ} \text{ C. and } T_2 = 363^{\circ} \text{ C.}$

The pressures corresponding to these temperatures were taken either directly, or by interpolation, from tables given in Vol. II. of Regnault's "Experiences" whenever it was possible. When, however, owing to the limited range of temperatures given in these tables, this was impossible, the following formula given by Wüllner, "Lehre von der Warme," p. 617, was resorted to—

$$\log S = a + ba^t + c\beta^t (5)$$

in which a, b, c, α and β are constants, tthe temperature on the Centigrade scale, and S the pressure in millimeters of mer-

For greater convenience of calculation Wüllner puts the constants in the following form:

-	а	Sign of bat	log. bat
Ether	5.4562028 5.0286298	_	.63903010029143 t .44143170031223 t
	5.4011662 5.2253893	_	.49188600022372 t .52199430025856 t

	$\operatorname*{Sign\ of}_{c\beta t}$	$\log . \ c eta t$		
Alcohol Ether Bi-sulph. of	++	$.5050675 - 30590515t \\ .6512970 - 4 + .0145775t$		
carb Chloroform	_	$ \begin{array}{c} .2799632 - 10119062t \\ .0888717 - 10131824t \end{array} $		

taken from a table of Regnault's results Substituting in (7) we have

given by Wüllner on p. 610 of "Lehre von der Warme."

The tensions found as just explained

	S ₁ .	p_1 .
Water. Alcohol Ether Bi-sulph. of carb. Chloroform		84,518 164,600 318,970 179,230 145,720

S, representing the tensions in millimeters of mercury, and p_1 the same tensions in kilograms on the square meter.

9. We now wish to find D, the weight in kilograms of a cubic meter of saturated

vapor at the temperature t.

On page 668, in his "Lehre von der Warme," Wüllner gives, as the result of the work of Herwig on the density of saturated vapors, the formula

$$V_1 = \frac{pv}{p_1 \times .0595\sqrt{a+t}} \quad . \quad . \quad (6)$$

in which V, =volume in cubic meters of one kilogram of saturated vapor at the absolute temperature a+t; p_1 =tension of the vapor in millimeters of mercury at that temperature; while p and v represent the pressure and volume that the vapor would have at that temperature if it obeyed Marriott's law. If we suppose the vapor far enough removed from the point of saturation to act as a perfect gas, the following law holds good:—

$$pv = p_{\scriptscriptstyle 0}v_{\scriptscriptstyle 0}(1+at) = a p_{\scriptscriptstyle 0}V_{\scriptscriptstyle 0}(a+t),$$

a+t being the absolute temperature corresponding to the temperature t, and V the volume of a unit weight of vapor under pressure p_{\bullet} at temperature O° Centigrade. If we let Vo' represent the volume of a unit weight of air under the same pressure and at the same temperature, the density of the vapor referred to air is

$$\delta = \frac{V_{o}'}{V_{o}} \cdot : V_{o} = \frac{V_{o}'}{\delta}.$$

Making this substitution, the product pv becomes

$$pv = \frac{\alpha p_{\scriptscriptstyle o} V_{\scriptscriptstyle o}'(\alpha + t)}{\delta} \quad . \quad . \quad (7)$$

For air, if $p_0 = 760$ m.m., $V_0' = .77339$ The tensions for vapor of water were cu. meters. For perfect gases $\alpha = .00366$.

$$pv = \frac{.00366 \times 760 \times .77339 \times (a+t)}{\delta},$$

which being substituted in (6) gives

$$V_{i} = \frac{.00366 \times 760 \times .77339 \times \sqrt{a+t}}{p_{i} \circ \times .0595}$$

Reducing we get

$$V_{1} = \frac{36.2\sqrt{a+t}}{p_{1}\delta} (8)$$

in which p_1 is the tension of the saturated vapor at temperature t_1 , and V_1 is the volume in cubic meters occupied by one kilogram of vapor at the same temperature.

It follows that the weight D₁ in kilograms of a cubic meter of saturated vapor is

$$D_1 = \frac{1}{V_1} = \frac{p_1 \delta}{36.2 \sqrt{a+t}} . . . (9)$$

The densities, δ , of the several vapors, referred to that of air, are given by Clausius in his "Mechanical Theory of Heat," page 59* and are

	0.
Water	.6219
Alcohol	1.5819
Ether.	
Bi-sulph. of carb	2.6258
Chloroform	

Substituting in equation (9) we find D_1 and D_2 corresponding to the temperatures $t_1=172^{\circ}$ C. and $t_2=90^{\circ}$ C.

	D ₁ .	D_2 .
WaterAlcohol Ether Bi-sulph. of carbChloroform.	5.07 25.18 78.66 45.37 57.84	.467 2.74 14.47 9.98 11.13

10. The latent heats, L_1 and L_2 , of evaporation per cubic meter of saturated vapor in kilogrammeters at temperatures t_1 and t_2 are now to be found.

On page 640 of "Lehre von der Warme," Wüllner gives the formula

$$\lambda = a + bt + ct^2 \quad . \quad . \quad . \quad (10)$$

for the latent heat of evaporation per kilogram at temperature t.

The constants for ether, bi-sulphide of carbon and chloroform are

	a.	ь.	c.
EtherBi-sulph. of carbChloroform	90	08922	0008514 0004938 0000507

For alcohol, a table of latent heats for every ten degrees up to 150° C. is given; and for water a similar table up to 194.8° C. (See p. 635 "L. v. d. W.")

From formula (10), in which the latent heats are given in calories, and from the

tables we get the results:

	λ_1 .	λ_2 .
Water	$159 \\ 55.2 \\ 60.1$	78

By multiplying these quantities by Joule's equivalent, 424 k. g. m., and the products by D_1 and D_2 respectively, we we get L_1 and L_2 .

	L_i .	L_2 .
Water	1,697,500 1,841,000 1,156,100	107,300 239,400 482,800 330,200 274,200

11. To find the mean specific heat K between t_1 and t_2 , we take the average of the specific heats at those temperatures.

On page 485, "L. v. d. W." is given the formula

$$K_t = A + 2Bt + 3Ct^2$$
 . . . (11)

for the specific heat at the temperature t. The specific heat of water is unity; the values of the constants for the other vapors are

	Α.	В.	С.
Alcohol			
Bi-sulph, of carb Chloroform	.23523 .23235	0000815 0000507	0

The mean specific heats between the temperatures 172° and 90° C. found as just explained are:

^{*} Browne's Translation, London, 1879. Vol. XXXI.—No. 5—29

Water	1
Alcohol	.966
Ether	.607
Bi-sulph. of carb	.257
Chloroform	.246

12. Having found the data necessary for substitution in equation (1), we may find the ratios of expansion. They are

Waterr=9.37	
Alcoholr=8.97	
Ether $r=6.11$	
Bi-sulph. of carb $r=3.96$	
Chloroform $r=5.22$	4

We may now discuss the action of each of the five vapors in working 1038300 k. g. m. of heat between the temperatures t_1 and t_2 .

The total work of expansion is given by formula (4), §6, and the work of compression by the next formula. All the quantities required for substitution in those formulas are known except v_1 and v_2 ; but $v_2 = rv_1$; therefore we have only to find v_1 . The amount of heat required to evaporate one cubic meter of vapor at temperature t_1 being given in §10, we may find the volume of each vapor generated by 1,038,300 k, g, m, by dividing 1,038,300 by the value of \mathbf{L}_1 in §10.

$v_1 = \frac{1,038,300}{L_1}$	(12)
Water	. 1
Alcohol	6116
Ether Bi-sulph, of earb	8980
Chloroform	8615

The amount of fluid used is v_1D_1 kilogs. Then we have (§6) Work of expansion=

$$\begin{split} \mathbf{JKD_{_{1}}}v_{_{1}}\bigg\{\tau_{_{1}} - \tau_{_{2}}\!\Big(1 + \log_{_{\cdot}\varrho}\frac{\tau_{_{1}}}{\tau_{_{2}}}\!\Big)\Big\} + \\ + \frac{\tau_{_{1}} - \tau_{_{2}}}{\tau_{_{1}}}\mathbf{L}_{_{1}} + v_{_{2}}p_{_{2}} \end{split}$$

Work of compression=

$$\mathbf{J} \mathrm{KD}_{\scriptscriptstyle 1} v_{\scriptscriptstyle 1} \bigg\{ \tau_{\scriptscriptstyle 1} - \tau_{\scriptscriptstyle 2} \bigg(1 + \log_{\scriptscriptstyle -e} \frac{\tau_{\scriptscriptstyle 1}}{\tau_{\scriptscriptstyle 2}} \bigg) \bigg\} + v_{\scriptscriptstyle 3} p_{\scriptscriptstyle 2}$$

Effective work=

$$\frac{\tau_1 - \tau_2}{\tau_1} \mathbf{L}_1$$

Substituting, we have

		Work of Compression
Water	274,767 331,322 466,740 354,120 347,474	83,408 139,863 275,381 162,761 156,115

	Effect've Work.	Heat Used.	Effi-
Water Alcohol	191,359 191,359 191,359	1,038,300 1,038,300 1,638,300 1,038,300	18.43 % 18.43 % 18.43 % 18 43 %
Chloroform	191,359	1,038,300	18.43 %

13. In the preceding, we have shown how the work of expansion and that of compression may vary greatly and still leave the effective work constant.

To show more clearly the action of the various vapors working in this cycle, we shall draw a diagram of Carnot's cycle for each case. To do this, it is necessary to find at least two more points in the curve of expansion, and the point at which adiabatic compression begins.

To find the points in the curve of expansion, we assume two temperatures, t_4 and t_5 between t_1 and t_2 , and find the corresponding volumes and pressures.

If we represent by r_4 and r_5 the ratios of expansion corresponding to the absolute temperatures t_4 and t_5 , formula (1) for the ratio of expansion becomes

$$r_4 \!=\! \! \frac{\tau_{_4}}{\mathrm{L}_{_4}} \! \! \left(\! \mathrm{JKD_1} \log . \quad \! \frac{\tau_{_1}}{\tau_{_2}} \!+\! \frac{\mathrm{L}_{_1}}{\tau_{_1}} \right)$$

in which L_4 and L_5 have their original signification. As $L_1 = D \times J \times \lambda$, we may make this formula more convenient in use by substituting for L_1 and L_4 their values. The formula then becomes

$$r_4 = \frac{\tau_4}{\lambda_4 D_4} \left(KD_1 \log_{e} \frac{\tau_1}{\tau_4} + \frac{\lambda_1 D_1}{\tau_1} \right) \quad (13)$$

In order to find r_4 and r_5 we need λ_4 , λ_5 , D_4 , D_5 , K, τ_4 , and τ_5 ; and to find D_4 D. we need p_4 and p_5 .

 D_{5}^{c} we need p_{4} and p_{5}^{c} . τ_{4} and τ_{5}^{c} were taken respectively as 418° and 393° C.

K is the same as before.

 λ is found as before in § 10, D as in § 9, p as in § 8, p being identical with p_1 of that article.

These quantities are

	p_4 . m. m.	р ₅ . m. m.	λ_4 .	λ ₅ .	D_4 .	D ₅ .	К.	D_1 .
Water	$\begin{array}{c} 6,485 \\ 12,957 \\ 8,237 \end{array}$	$\begin{array}{c} 1,491 \\ 3,232 \\ 7,719 \\ 5,149 \\ 3,926 \end{array}$	504.7 173.1 64.6 66.7 52.2	522.6 186.8 72.3 72.2 54.9	2.63 13.87 44.82 29.26 36.85	$ \begin{array}{c} 1.29 \\ 7.16 \\ 27.50 \\ 18.90 \\ 22.50 \end{array} $	1 .966 .607 .237 .246	5.07 25.18 78.66 45.37 57.84

Substituting these values we get r_4 and r_5 the following:

	r_4 .	$v_4 = r_4 v_1$.	r_5 .	$v_5 = r_5 v_1$.
Water Alcohol. Ether. Bi-sulph. of carb. Chloroform	1.83 1.85 1.47	1.83 1.12 1.04 1.32 1.36	3.51 3.54 3.11 2.18 2.60	3.51 2.17 1.75 1.95 2.24

14. It is now necessary to find the point at which adiabatic compression begins. This is done as follows:—At the point D, at which adiabatic compression begins, the mixture of liquid and vapor has the pressure p_2 and volume v_c . This mixture is then made by compression to assume a volume, 0^* , under pressure p_1 and at temperature t_1 , when it becomes reduced entirely to the liquid state. If the fluid now expand adiabatically until it takes the volume v_c =ED under pressure p_2 , it will perform the work represented by ADF OA, which may be divided into two parts,

$$\begin{split} \text{EDFO} \!=\! p_{\scriptscriptstyle 2} \, v_{\scriptscriptstyle 6}\!, \text{ and } \text{ADE} \!=\! \text{JKD}_{\scriptscriptstyle 1} v_{\scriptscriptstyle 1} \\ \left\{ \tau_{\scriptscriptstyle 1} \!-\! \tau_{\scriptscriptstyle 2} \left(\! 1 \! + \! \log_{\cdot e} \frac{\tau_{\scriptscriptstyle 1}}{\tau_{\scriptscriptstyle 2}} \right) \right\} \end{split}$$

We have assumed, for convenience of illustration, that the fluid is expanding instead of being compressed. This we may do without error, as the operations of expansion are exactly those of compression reversed.

At the point A, Plate I., Fig. 1, we have D_1v_1 kilograms of liquid at temperature t_1 , at the point D the same weight of liquid and vapor is under pressure p_2 at temperature t_2 and occupies the volume v_3 . Since this expansion is adiabatic, the difference between the sensible heats existing at A and D has been entirely converted, either into work, or into latent heat of evaporation. This amount of heat is

$$\begin{aligned} \mathbf{H} \!=\! \mathbf{D_{_1}} \!\times\! v_{_1} \!\!\times\! \mathbf{K} \!\times\! (t_{_1} \!-\! t_{_2}) \!\times\! 424 \\ \text{expressed in kilogrammeters.} \end{aligned}$$

The work done during expansion is

$$\begin{aligned} \text{ADFOE=JKD}_{1}v_{1} \left\{ \tau_{1} - \tau_{2} \left(1 + \log_{-\epsilon} \frac{\tau_{1}}{\tau_{2}^{\epsilon}} \right) \right\} \\ + p_{2} v_{e^{*}} \end{aligned}$$

The amount of sensible heat that has become latent is that required to evaporate

 $D_2 v_6$ kilogs. of vapor.

As the evaporation takes place not at any particular temperature, but throughout the entire range from t_1 to t_2 , we have taken as the latent heat of evaporation the average of the latent heats at the temperatures t_1 and t_2 , which per kilogram is $\lambda + \lambda$

 $\frac{\kappa_1 + \kappa_2}{2}$. Hence the amount of heat which has become latent is, in kilogrammeters,

$$D_{_{2}} v_{_{6}} \times \frac{\lambda_{_{1}} + \lambda_{_{2}}}{2} + 424.$$

As all the sensible heat that has disappeared has been either changed into work or into latent heat, we may write the equation

$$\begin{split} & \mathbf{D_1} \, v_1 \, \mathbf{K} \! \times \! (\tau_1 \! - \! \tau_2) \! \times \! 424 \! = \\ & \mathbf{J} \mathbf{K} \mathbf{D_1} v_1 \! \left\{ \tau_1 \! - \! \tau_2 \! \left(\! 1 \! + \! \log_{\cdot e} \frac{\tau_1}{\tau_2} \right) \right\} + \\ & + p_2 \, v_6 \! + \! \mathbf{D_2} \, v_6 \frac{\lambda_1 + \lambda_2}{2} \! \times \! 424 \end{split}$$

It may be seen by inspection that all the quantities in this equation are known except v_c . We can therefore find v_c , and hence, D. Solving for v_c , we have

^{*} The volume occupied by the fluid in the liquid state is so small in comparision with that assumed by the vapor that it may be considered as equal to 0.

$$v_{e} = rac{ \operatorname{JKD_{1}}v_{1} \left\{ \left. \left(t_{1} - t_{2} \right) \times 424 - \right. \right. }{ \left. \left. \left. \left(1 + \log_{e} \frac{ au_{1}}{ au_{2}} \right) \right. \right\} }{ \left. \left. \left(p_{2} + \operatorname{D_{2}} \frac{\lambda_{1} + \lambda_{2}}{2} \times 424 \right) \right. \right\} }$$

solution of this equation, those used in substituting in previous equations and the results of substitution, are given in the following tables in both metric and British units.

The diagrams showing the behavior of each of the vapors when worked in Car-

15. The quantities necessary for the not's cycle, are found in Fig. 2 of Plate 1.

TABLE I. DATA AND RESULTS FOR CASE I. METRIC UNITS.

Vapors.	$t_{_1}$.	t_2 .	$t_{_4}$.	$t_{\mathfrak{s}}.$	τ,.	$ au_{_2}$.	$ au_4$.	$ au_{\mathfrak{s}}.$
Water	Cent. 172 172 172 172 172 172	Cent. 90 90 90 90 90	Cent. 145 145 145 145 145 145	Cent. 120 120 120 120 120 120	Cent. 445 445 445 445 445	Cent. 363 363 363 363 363	Cent. 418 418 418 418 418	Cent. 393 393 393 393 393

Vapors.	p_1 .	p ₂ .	p_4 .	p ₅ .	λ_1 .	λ_2 .	λ_4 .	λ_5 .
Water	\$4,518 164,600 318,970 179,230	7,043	Kgms on sq. mets. 42,500 87,829 176,215 112,023 90,005	Kgms on sq. mets. 20,278 43,955 104,978 70,026 53,394	Calories. 483 159 55.2 60.1 49.2	Calories. 542 206 80 78 58.1	Calories. 504.7 173.1 64.6 66.7 52.2	Calories. 522.6 186.8 72.3 72.2 54.9

Vapors.	D ₁ .	D_2 .	D_4 .	D_5 .	r.	r_4 .	r_5 .	$_{k}$.
				Kgms pr cu. met.				
Water	25.18 78.66 45.37	.467 2.74 14.47 9.98 11.13	2.63 13.87 44.82 29.26 36.85	1.29 7.16 27.50 18.90 22.50	9.37 8.97 6.11 3.96 5.22	1.83 1.83 1.85 1.47 1.58	3.57 3.54 3.11 2.18 2.60	1 .966 .607 .257 .246

Vapors.	v_1 .	v ₂ .	v_4 .	v ₅ .	Work of Expansion	Work of Compression	Effective Work.	Heat Used.	Effi- ciency
	cubic mets.				Kilogram- meters.	Kilogram- meters.	Kilogram- meters.	Kilogram- meters.	Per cent.
Water	1	9.37	1.83	3.57	274,767	83,408	191,359	1,038,300	18.43
Alcohol Ether	.5640	3.45	1.04	1.75	466,740	139,863 $275,381$	$191,359 \\ 191,359$	1,038,300 $1,038,300$	18.43 18.43
Carbon di-sulphide Chloroform	.8980	$\frac{3.56}{4.50}$	1.32	$\frac{1.95}{2.24}$	$354,120 \\ 347,474$	162,761 $156,115$	191,359 $191,359$	1,038,300 $1,038,300$	$18.43 \\ 18.43$
Chiorotoria	.0010	1.00	1.00	~.~1	011,111	250,115	101,000	2,000,000	20123

Table II. DATA AND RESULTS FOR CASE I. BRITISH UNITS.

Vapors.	$t_{_1}$	t_2 t_2		$t_{\scriptscriptstyle 5}$	7	1	τ,	2	$\tau_{_4}$	τ	5	p_1
Water	342 342 342 342	Fah. Fa 194 194 194 194 194 194 194 194	3 3	Fah. 248 248 248 248 248	803 803 803 803 803 803	2 .2 .2 .2	Fa 655 655 655 655 655	2 2 2 2	Fah. 754.2 754.2 754.2 754.3 754.2	Fa 709. 709. 709. 709.	2 2 2 2 2	Lbs. on sq. foot. 17,310 33,712 65,328 36,708 29,845
Vapors.	p_2	p_4		p_{5}	\- λ ₁		λ_2	λ_4	2,5		D_1	D_2
Water	Lbs. on sq. foot. 1,442 3,312 10,858 7,295 5,189	Lbs. on sq. foot. 8,705 17,989 36,090 22,943 18,433	sq. 4 9 21 14	s. on foot. ,153 ,003 ,501 ,342 ,936	Ther unit 869. 286. 99. 108. 92.	ts. 4 2 4 2	Ther. units. 975.6 370.8 144 140.4 104.6	uni 908 311 116 120	ts. unit .5 940. .6 336. .3 130. .1 130.	s. cu. 7 2 1 1 4 5 6 5 8		Lbs. per cu. foot. .029 .171 .903 .623 .695
Vapors.	D_4	D ₅	1		r_4	$r_{\mathfrak{s}}$	5	v_1	v 2		v_4	v 5
Water		Lbs. per cu. foot. .081 .447 1.717 1.180 1.405		$ \begin{array}{c cccc} 97 & 1 \\ 11 & 1 \\ 96 & 1 \end{array} $	1.83 1.83 1.85 1.47 1.58	3.5 3.5 3.1 2.1 2.6	51 1 54 .6 .1 .5 .8 .8	. feet. 3116 5640 3980 3615	Cu. fee 9.37 5.48 3.45 3.56 4.56	1 1 1	. feet. .83 .12 .04 .32 .36	Cu. feet. 3.51 2.17 1.75 1.95 2.24
Vapors.	К	Work Expansi			ork of pressi		Effec Wo		Heat	used.	Eff	ficiency.
Water	1 .966 .607 .257 .246	Kilog'me 56,27 67,85 95,59 72,52 71,166	5 7 3 7	1 2: 5: 3:	g'mete 7,083 8,645 6,401 3,335 1,974	ers I	Xilogʻr 39, 39, 39, 39,	192 192 192 192	Kilog' 212, 212, 212, 212, 212, 212,	654 654 654 654	18 18 18 18	3.43 ¢ 3.43 ¢ 3.43 ¢ 3.43 ¢ 3.43 ¢

Case II.

16. The object of this case is to determine which of the fluids—water, alcohol, ether, bi-sulphide of carbon and chloroform-would be most suitable as the working fluid of an engine, if worked as saturated vapor in a non-conducting cylinder between the limits of pressure usually employed in the steam engine.

Rankine's formulas, eqs. (1) and (2), for ratio of expansion and work done to this pressure are found in tables are applicable to this case, and we must given by Regnault in his "Expériences." now find the quantities necessary for and are-

substitution. These quantities, together with a brief statement of how they are obtained, will be given, and, at the end of this division, the necessary data and results will be tabulated in both metric and British units.

17. The pressures assumed are $p_1 =$ 6214.6 mm. of mercury, or 84518 kilograms per square meter, $p_2 = 517.9$ mm. of mercury, or 7403 kilograms per square meter. The temperatures corresponding

	$t_{_{1}}$.	t_2 .	τ,.	$ au_{2}$.
WaterAlcohol			445 417	363
Ether	110	$24\frac{1}{2}$	383	$\frac{342}{297\frac{1}{2}}$ $\frac{308}{2}$
Chloroform			414	

To find D_i, the weight in kilograms per cubic meter of saturated vapor, we have formula (9)—

$$D_{1} = \frac{p_{1}\delta}{36.2\sqrt{a+t}}$$

The values of δ are given in §9. Substituting in the formula, we get,

	D_1 .	$D_{\mathfrak{s}}.$
Water. Alcohol Etner. Bi-sulph. of carb. Chloroform		.467 1.23 2.12 2.14 3.29

The latent heats of evaporation, L_1 and L_2 , per cubic meter of vapor at temperature t_1 and t_2 , expressed in kilogrammeters are found as in §10, and are—

	L_{i} .	L ₂ .
Water	985,600 $713,000$	$107,300 \\ 115,256 \\ 82,337 \\ 78,305$
Chloroform		86,766

The mean specific heats are found as in §11, but will differ from those previously found, as the ranges of temperature are not the same. They are—

	К.
Water	1
Alcohol	
Ether	569
Bi-sulp. of carb	249
Chloroform	

It is to be remembered that t_1 and t_2 have different values for each of the vapors.

18. Having now all the data necessary for substitution in formula (1),

$$r = \frac{\tau_2}{L_0} \left(\text{JKD}_1 \log_{e} \frac{\tau_1}{\tau_0} + \frac{L_1}{\tau_1} \right)$$

we may find the ratios of expansion, which are—

$r = rv_1 = v_2$.
Water 9.37
Alcohol
Ether
Bi-sulph. of carb 9.00
Chloroform

To find the work done we substitute in formula (2),

$$\begin{aligned} \mathbf{W} \! = \! \mathbf{w} \mathbf{o} \mathbf{r} \mathbf{k} \! = \! \mathbf{J} \mathbf{K} \mathbf{D}_{1} \! \left\{ \left. \boldsymbol{\tau}_{1} \! - \! \boldsymbol{\tau}_{2} \! \left(1 \! + \! \log \left. e \frac{\boldsymbol{\tau}_{1}}{\boldsymbol{\tau}_{2}} \right) \right. \right\} + \\ + \frac{\boldsymbol{\tau}_{1} \! - \! \boldsymbol{\tau}_{2}}{\boldsymbol{\tau}_{1}} \mathbf{L}_{1} \! + \! r \left(\boldsymbol{p}_{2} \! - \! \boldsymbol{p}_{3} \right) \end{aligned} \right. \end{aligned}$$

To this substitution, we have all the quantities except p_s , the back pressure, which is determined by the temperature of the condenser. As the temperature of the condenser cannot easily be kept lower than 104° Fahr., or 40° Centigrade, we have assumed that to be its temperature, and p_s must, in each case, be the tension of the vapor corresponding to this temperature.

From Regnault's tables we have,

p_3 (m.m. of Mercury).	p_3 (kilogs, per sq. meter).
55 134	748 1,825
907 618 366	$ \begin{array}{c} 12,335 \\ 8,405 \\ 4,973 \end{array} $
	55 134 907 618

Making the proper substitutions we obtain for work done:

Water	267,705	kilogrammeters.
Alcohol		
Ether	151,643	"
Bi-sulph. of carb		
Chloroform		

19. To determine the efficiency of fluid of the several vapors, we must first find the heat expended per cubic meter of vapor at temperature t_1 . As the feed for the boiler is taken from the surface-condenser, its temperature is t_2 . The heat used is then the amount necessary to raise D_1 kilograms of liquid from temperature t_2 to t_1 , and to evaporate them at that temperature.

20. This is most easily found by calculating the total heat of evaporation from 0° C. to t_{1} , and subtracting from this quantity the heat required to raise the liquid from 0° to t_{2} .

The total heaf of evaporation per kilogram from 0° to t is given by the formula

Q=A+Bt+C t^2 (p. 640, Wüllner's "L. v. d. W.").

The constants for ether, bi-sulphide of carbon and chloroform, are—

	A.	В.	C.
Ether. Bi-sulph. of carb Chloroform	90	.4500 .14601 .1375	$ \begin{array}{r}0005555 \\0004123 \\ 0 \end{array} $

The value for alcohol was determined from the table on page 641, "L.v. d. W." by interpolation, and that for water was determined by the same method from the table on p. 635 of the same work.

The total heats of evaporation at temperature t_i per kilogram, expressed in

calories, are—

	t_1 .	Q_1 .
Water. Alcohol Ether Bi-sulph. of carb. Chloroform.	172 144 110 130 141	$\begin{array}{c} 659.0 \\ 282.5 \\ 136.8 \\ 102.0 \\ 86.4 \end{array}$

The same quantities for D₁ kilogs. of vapor, expressed in kilogrammeters, are given by

 $H_1 = 424 \times D_1 \times Q_1$

and are

	H_1 .
Water	1,416,639
Alcohol	1,600,261
Ether	1,300,431.7
Bi-sulph. of carb	969,188
Chloroform	

The amount of heat, h_s , expressed in mechanical units, necessary to raise the temperature of the liquid from 0 to t_s is found by multiplying the mean specific heat for that range of temperature by (t_s-0) , D_s and 424.

On page 483, "L.v. d. W," the following formula is given for the mean

specific heat between 0 and t:

$$C_t = A + Bt + Ct^2$$

in which A, B and C have the values given in §11.

Hence,

$$h_3 = C_t \times D_1 \times 40 \times 424$$
.

The values of h_3 are

	$n_{\rm g}$.
Water	86,000
Alcohol	
Ether	
Bi-sulph of carb	
Chloroform	
OHIOIOIOIH	CO.001

The efficiency of fluid is the work divided by the mechanical equivalent of the heat used, or

$$\mathbf{E} = \frac{\mathbf{W}}{\mathbf{H}_{1} - h_{3}} = \frac{\mathbf{W}}{\mathbf{H}}$$

	$\mathbf{H} = \mathbf{H}_1 - h_3$.	E.
WaterAlcohol	1,330,639 1,465,207	20.12 % 18.06 %
EtherBi-sulph. of carb	1,094,722	13.85 % 19.75 %
Chloroform		20.46 %

These efficiencies are different, as they should be, the fluids being worked through

different ranges of temperature.

To show the relation between the power developed per stroke, and the size of cylinder for each of these vapors, the power developed in a cylinder one cubic meter in volume is calculated. As, in the problem just discussed, the initial volume of vapor was one cubic meter, the volume of cylinder, v_2 , required for its working is r cu. meters. It thus follows that, in a cylinder of one cubic meter capacity, the work done would be

The values of this ratio are—

	W
	r
Water	28,570
Alcohol	
Ether	
Bi-sulph. of carb	
Chloroform	22,590

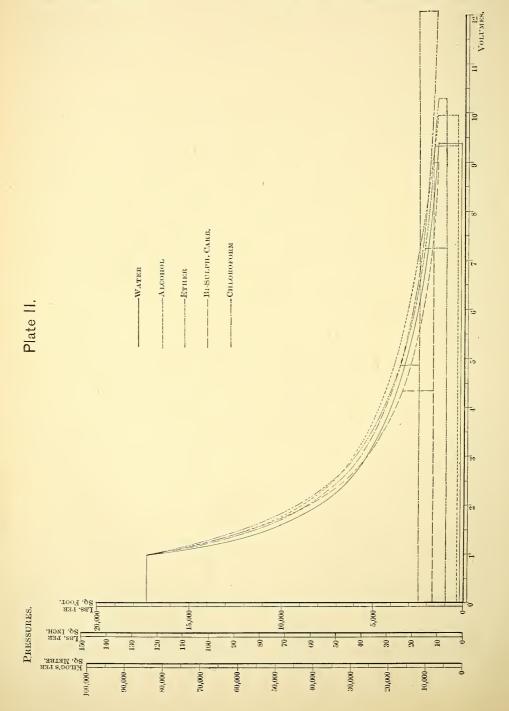
To render the comparison of these numbers easier, the ratio of each to that of water is taken. These ratios give the relative powers developed in cylinders of the same size; their reciprocals give the relative volumes of cylinder required to produce the same power.

	Ratio.	Reciprocal.		
Water		1. 1.071		
EtherBi-sulph. of carb	.676	2.275 1.480		
Chloroform	.791	1.264		

From the above, it is seen that steam requires the smallest cylinder to produce a given power, if worked between the limits of pressure we have taken. It is also more efficient than any of the vapors, except chloroform. The losses due

to the larger cylinder necessary to work chloroform would probably bring down its efficiency in practice, at least to that of steam if not lower. So far, then, it pansion would take place in a heat-enwould seem that steam is the best fluid gine cylinder. These cards are shown in to use in heat engines.

23. As a matter of interest, we have Plate II. Two temperatures, t_{\bullet} and t_{\circ} ,



were taken between t_1 and t_2 , and the corresponding pressures found from tables in Regnault's "Expériences," or by the formula (5) of §8. The volumes were calculated by Rankine's formula for ratio of expansion, as modified in §13; the initial volume being unity, the formula becomes-

$$r_4 = \frac{\tau_4}{\lambda_4 D_4} \left(\text{KD}_1 \log_{e} \frac{\tau_1}{\tau_4} + \frac{\lambda_1 D_1}{\tau_1} \right)$$

 λ_4 and λ_5 were calculated as in §10, and in them.

METRIO UNITS.

 τ_1 , absolute initial temperature on the C. scalc.

 $\tau_{\rm g}$, absolute final temperature on same scale.

 τ_4 and τ_5 , absolute temperatures of intermediate points.

 t_1 , temperature on C. seale, corresponding to absolute temperature τ .

 t_3 , temperature of eondenser.

p, tension of vapor in kilogs. per sq. meter at temperature t.

7, latent heat of evaporation in calories of 1 kilog. of vopor at temperature t.

L, latent heat of evaporation in k g.m. at tem- L, latent heat of evaporation of 1 eu. ft. of vaperature t of 1 eu. m. of vapor.

v, volume corresponding to ratio of expansion v, volume corresponding to ratio of expansion

w, work (in k.g.m.) done per cu. m. of vapor at w, work (in ft. lbs.) done per cu. ft. of vapor at temperature t_1 .

H, total heat (in k. g.m.) used per cu. m. of va- H, total heat (in ft. lbs.) used per cu. ft. of por at temperature t.

F, kilograms used per H. P. per hour.

power.

D₄ and D₅ as in §9. K is nearly the same as in §7.

In Tables III. and IV. are given, in both metric and British units, all the data necessary for this case, together with the results of substitution.

The final volume, $v_2 = rv_1$; but as $v_1 = rv_2$ 1, $v_2 = r$; hence, v_2 and not r, is found in the tables.

24. Before giving the tables, we shall define the various quantities that appear

British Units.

 τ_1 , absolute initial temperature on the Fahr.

 τ_2 , absolute final temperature on same scale.

 τ_4 and τ_5 , absolute temperatures of intermediate

 t_1 , temperature on F. scale corresponding to absolute temperature τ_{i} .

 $t_{\rm a}$, temperature of condenser.

p, tension of vapor in lbs. per square ft. at temperature t.

λ, latent heat of evaporation in British thermal units of 1 lb. of vapor at temperature t.

por in ft. lbs. at temperature t.

temperature t_1 .

vapor at temperature t.

F, lbs. used per H. P. per hour.

M, relative size of cylinder to produce the same M, relative size of cylinder to produce the same

Table III. DATA AND RESULTS IN CASE II. METRIO UNITS.

Vapors.	$\tau_{_1}$	$ au_{_2}$	$\tau_{_4}$	$\tau_{_{6}}$	t_1	t_{s}	$\mathbf{D}_{_{1}}$	D,	1),
Water	$417 \\ 383 \\ 403$	363 342 297.5 308 322	418 393 393 393 393	393 353 353 353 353	172 144 110 130 141	40 40 40 40 40	5.07 13.36 22.42 22.41 34.78	2.63 3.86 18.14 12.50 14.31	1.29 1.90 11.40 7.80 8.50

Vapors.	p_1	p_2	p_3	p_4	p_5	λ_1	2.4	2.5	К
Water	84,518 84,518 84,518	7,043 7,043 7,043 7,043 7,043	748 1,822 12,335 8,405 4,978	42,500 23,093 67,361 45,220 33,021	20,278 11,057 41,113 27,649 25,894	483 174 75 70 52.6	504.7 199. 77.6 76.1 57.	522.6 213. 82.2 79.7 59.1	1 .871 .569 .249 .242

Vapors.	L_{ι}	L_2	v_2	v_4	v_5	w	Н	Е	М	F
Water	$\begin{array}{c} 985,600 \\ 713,000 \\ 665,100 \end{array}$	115,256 82,337 78,305	$9.92 \\ 12.06 \\ 9.00$	$ \begin{array}{r} 3.97 \\ 1.25 \\ 1.87 \end{array} $	8.12 2.05 3.06	264,617 151,643 173,553	$\begin{array}{c} 1,330,639 \\ 1,465,207 \\ 1.094,722 \\ 878,729 \\ 1,136,085 \end{array}$	18.06 % 13.85 % 19.75 %	1.071 2.275 1.480	35.46

TABLE IV.

DATA AND RESULTS IN CASE II.

BRITISH UNITS.

Vapors.	$\tau_{_1}$	$\tau_{_2}$	$\tau_{_4}$	$ au_{_{5}}$	$t_{!}$	$t_{_3}$	D,	$\mathrm{D}_{\scriptscriptstyle{4}}$	$\mathbf{D}_{\mathfrak{s}}$
Water	752 691 727	655 617 537 556 581	754 673 673 673 673	709 637 637 637 637	342 291 230 266 286	104 104 104 104 104	.317 .834 1.400 1.399 2.171	.164 .241 1.132 .780 .893	.081 .119 .712 .487 .531

Vapors.	p_1	p_2	p_3	p_4	p_5	λ_1	λ_4	λ_5	К
Water	17,310 17,310 17,310	1,442 1,442 1,442 1,442 1,442		8,703 4,730 13,796 9,261 6,763	4,512 2,264 8,420 5,663 3,911	869.4 313.2 135.0 126.0 94.7	908.5 358.2 139.7 137.0 102.6	940.7 383.4 148.0 143.5 106.4	1 .871 .569 .249 .242

Vapors.	$\mathbf{L_{1}}$	L_2	v_z	v_4	v 5	w	Н	Е	М	F
Water	201,861 146,030 136,219	23,606 16,863 16,038	$9.92 \\ 12.06 \\ 9.00$	3.97 1.25 1.87	$8.12 \\ 2.05 \\ 3.06$	54,196 31,058 35,545	300,088 $324,206$ $179,973$	18.06 % 13.85 % 19.75 %	1.071 2.275 1.480	11.44 30.48 89.24 78.15 90.30

25. From the indicator cards shown in Plate II., it may be seen that the ratios of expansion adopted in the last case are not most economical, especially in the cases of ether and bi-sulphate of carbon, in which cases the final pressure is lower than the back pressure, causing a loop in the expansion and exhaust lines. It has been found in steam-engine practice that it is not economical to expand down to the back pressure, the best results having been obtained when there is a difference between final and back pressure of from 7 to 10 lbs. on the square inch. It is probable that the best practical results, in the cases of the other vapors, would be obtained by producing a similar difference between final and back pressure. This assumption suggests a modification of Case II., which is given as Case III.

CASE III.

26. In this case we have taken the same initial pressures as in the last, but have determined the final pressure by adding a nearly constant quantity to the back pressure, which latter pressure is determined by the temperature of the condenser, 40° C.

The formulæ (1) and (2) used to find the ratio of expansion and work done are the same as used in the last case. The symbols having subscripts (1) and (3) are the same as in the preceding case, those quantities represented by symbols having (2) for a subscript must now be found.

The pressures p_2 and p_3 are given below in kilograms on the square meter.

	p_2 .	p_3 .
Water	7,043 7,358 17,190 15,844 10,214	748 1,828 12,335 8,405 4,978

tables in Regnault's "Expériences." D is determined as in § 9; λ_2 as in § 10. With these data, and those of Case II. we may now find the values of the new ratio of expansion work done, and efficiency.

27. The data for this problem, together with the results obtained, are to be found in Tables V. and VI., in which the letters The temperatures t_2 corresponding to at the heads of the columns have the the pressures p_2 , were found from the same signification as explained in § 24.

Table V. DATA AND RESULTS IN CASE III. METRIC SYSTEM.

Vapors.	$\tau_{_1}$	T ,	$\tau_{_4}$	τ_{5}	$t_{_1}$	$t_{\mathfrak{s}}$	D_{i}	D_2	$\mathbf{D}_{_{4}}$	D_{5}
Water. Alcohol. Ether. Carbon di-sulphide. Chloroform.	417 383 403	363 343 323 333 333	418 393 393 393 393	393 353 353 353 353	172 144 110 130 141	40 40 40 40 40	5.07 13.36 22.42 22.41 34.78	.467 1.28 4.97 4.63 4.69	2.63 3.86 18.14 12.50 14.31	1.29 1.90 11.40 7.80 8.50

Vapors.	$p_{_1}$	$p_{_2}$	p_{s}	$p_{_4}$	$p_{\scriptscriptstyle 5}$	λ_{i}	λ_4	λ_{5}	К	L,	$\mathbf{L}_{_{2}}$
WaterAlcohol. Ether. Carb. di-sulph. Chloroform	84,518 84,518 84,518	7,358 17,190 15,844	1,822 12,335 8,405	67,361 $45,220$	41,113 $27,649$	174 75 70	$199 \\ 77.6 \\ 76.1$	82.2 79.7	.871 $.569$ $.249$		119,941 185,226 162,743

Vapors.	v_2	v_4	v_{5}	w	Н	Е	М
Water	$9.51 \\ 4.85 \\ 4.31$	1.83 3.97 1.25 1.87 2.68	3.57 8.12 2.05 3.06 4.66	267,705 262,614 162,869 162,875 219,200	1,330,639 1,465,207 1,094,722 878,729 1,136,084	20.12 % 17.92 % 14.88 % 18.53 % 19.29 %	1 1.035 .845 .756 .944

TABLE VI. DATA AND RESULTS IN CASE III. BRITISH UNITS.

Vapors.	$\tau_{_1}$	$\tau_{_2}$	$\tau_{_4}$	$\tau_{_{5}}$	$t_{_1}$	$t_{_3}$	$\mathbf{D}_{\mathbf{i}}$	D_{2}	D_4	$D_{\mathfrak{s}}$
Water Alcohol Ether Carbon di-sulphide. Chloroform	$\frac{691}{727}$	655 619 583 601 601	754 673 673 673 673	709 637 637 637 637	342 291 230 266 286	104	.317 .834 1.400 1.399 2.171	.029 .080 .310 .289 .293	.164 .241 1.132 .780 .893	.081 .119 .712 .487 .531

Vapors.	p_1	p_2	p_3	p_4	p_{5}	λ_1	λ ₄	λ ₅	К	L_1	L_2
Water	17,310 17,310 17,310	1,507 3,524 3,245	373 $2,526$ $1,721$	$13,796 \\ 9,261$	2,264 $8,420$ $5,663$	$313.2 \\ 135.0 \\ 126.0$	$358.2 \\ 139.7 \\ 137.0$	383.4 148.0 143.5	.871 .569 .249	212,650 201,861 146,030 136,219 158,851	21,980 24,565 37,936 33,331 24,885

Vapors.	v_2	v_4	v_5	w	Н	E	M
Water Alcohol Ether Carbon di-sulphide Chloroform.	9.51	1.83 3.97 1.25 1.87 2.68	3.51 8.12 2.05 3.06 4.66	54,829 53,786 33,357 33,358 44,894	1,330,639 1,465,207 1,094,722 878,729 1,136,084	20.12% 17.92% 14.88% 18.53% 19.29%	1 1.035 .845 .756 .944

given in Plate II.

ratio of expansion.

28. On comparison with Tables V. and VI. with Tables III. and IV., it will be seen that the efficiences in the latter case are greater than those in the former. It must be remembered, however, that in practice the losses by friction and condensation due to greater ratios of expansion in Problem II. will probably more than compensate for this small increase of useful work. Tables V. and VI. show, further, that steam has an advantage over all the other vapors in efficiency, and over alcohol in size of cylinder, while bi-sulphide of carbon excels all the others in the latter respect.

Case IV.

ture used in the steam engine. The fore explained.

The indicator cards for this case are pressures assumed in the two preceding They differ from problems were $p_1=84,518$ kilograms per those of Case II. only in the value of the square meter, and $p_z=7{,}043$ kilograms ratio of expansion. per square meter. saturated water vapor under these pressures are $t_1 = 172^{\circ}$ C., and $t_2 = 90^{\circ}$ C. The temperature of the condenser is, as before, taken as 40° C., which is as low as it could be conveniently kept in practice.

> The tensions of the saturated vapors of alcohol, ether, bisulphide of carbon, and chloroform, at these temperatures, have already been found in Case 1, § 8. In the same problem were also determined the values of D₁ and D₂, § 9; of λ_1 and λ_2 , § 10; of K, § 11, and of r, § 12; while § 13 furnishes the value of D_4 , D_5 , λ_4 , λ_5 ,

 p_*, p_*, r_* , and r_{ϵ} . Tables VII. and VIII. contain the data and results for this case; the corresponding indicator cards are found in Plate 29. In Cases II. and III. we have con-III. As the initial volume v_{ij} , in the case sidered the behavior of the several va- under consideration, is one cubic meter, pors in question when used as working the final volumes, v_2 , v_4 and v_5 , will be fluids between the limits of pressure different from the similar quantities in common in the modern steam engine. Case I., and will be numerically equal to We shall now proceed to discuss, in the ratios of expansion r_1 , r_4 and r_5 . The Cases IV. and V., their behavior when letters at the head of the columns of the worked between the limits of tempera- tables have the same signification as be-

Table VII. DATA AND RESULTS FOR CASE IV. METRIC UNITS.

Vapors.	$t_{_1}$	t_{2}	$t_{_3}$	$t_{_4}$	t_{5}	$\tau_{_1}$	$ au_{_2}$	$\tau_{_4}$	$\tau_{_{5}}$
Water	172 172 172	90 90 90 90 90	40 40 40 40 40	145 145 145 145 145 145	120 120 120 120 120 120	445 445 445 445 445 445	363 363 363 363 363	418 418 418 418 418	393 393 393 393 393

Vapors.	p_1	$-p_2$	p_3	p_4	p_{5}	λ_1	1.2	7.4	7.5	К	
Water	84,518 164,600 318,970 179,230 145,720	7,043 16,170 53,013 35,618 25,337	748 1,822 12,335 8,405 4,978	42,500 87,829 176,215 112,023 90,005	20,278 43.955 104,978 70,026 53,394	159 55.2 60.1	78	504.7 173.1 64.6 66.7 52.2	522.6 186.8 72.3 72.2 54 9	1 .966 .607 .257 .246	
Vapors.	D_1	D_2	D_2		D_5	v	2	v_4	-	v ₅	
Water	5.07 25.18 78.66 45.37 57.84	$ \begin{array}{c c} 2.74 \\ 14.4 \\ 9.9 \end{array} $.467 2.74 14.47 9.98 11.13		1.29 7.16 27.50 18.90 22.50	9·37 8.97 6.11 3.96 5.22		1.88 1.88 1.88 1.47 1.58	3 5 7 2	.57 .54 .11 .18 .60	
Vapors.	w		Н.		E.		F.	3	I.		
Water Alcohol Ether Carbon di-sulphide Chloroform		. 525,0 751,8 360,8	086 821 878	1,330,65 2,894,96 4,447,85 1,798,25 2,002,15	04 23 75	20.12% 18.14% 16.90% 20.07% 18.81%		5.19 13.13 28.64 34.41 42.06		488 232 314 396	

TABLE VIII. DATA AND RESULTS FOR CASE IV. BRITISH UNITS.

						1		-		
Vapors.	$t_{_1}$	t_2	t_{s}	t_{4}	$t_{\scriptscriptstyle 5}$	$\tau_{_1}$	$ au_{_2}$	7	4	$\tau_{_{\mathfrak{b}}}$
Water	342 342 342	194 194 194	104 104 104	293 293 293 293 293 293	248 248 248 248 248	803.2 803.2 803.2 803.2 803.2	655.2 655.2 655.2 655.2 655.2	75 75 76	4.2 4.2 4.2 4.2 4.2 4.2	709.2 709.2 709.2 709.2 709.2 709.2
Vapors.	$p_{_1}$	p_2	$p_{_3}$	í	04	$p_{\mathfrak{s}}$	λ_{i}	λ_2	λ_4	λ_{5}
Water	17,310 33,712 65,329 36,708 29,845	1,442 3,312 10,858 7,295 5,189	153 373 2,526 1,721 1,020	17 36 22	,705 ,989 ,090 ,943 ,433	4,153 9,003 21,501 14,343 10,936	286.2 99.4 108.2	975.6 370.8 144 140.4 104.6	908. 311. 116. 120. 94.	6 336.2 3 130.1 1 130.0
Vapors.	К	D_1	D_2		$\mathrm{D_4}$	D_5	v ₂	v	4	V ₅
Water	1 .966 .607 .257 .246	.317 1.572 4.911 2.832 3.611 .695		.71 .866 2.798 323 1.827		.081 .447 1.717 1.180 1.405	9.37 8.97 6.11 3.96 5.22	1 1. 1.	83 83 85 47 58	3.51 3.54 3.11 2.18 2.60
Vapors.		W.		н.		E.	F			М.
Water		54,829 107,543 153,980 73,911 77,114	54,829 273 107,543 573 153,980 910 73,911 368		1	20.12% 18.14% 16.90% 20.07% 18.81%	28 63 75	.45 .94 .15 .87 .72		.488 .232 .314 .396

CASE V.

to Case IV. that Case III. bears to Case II. In the preceding case we did not for the reasons already stated in § 25, we shown in Plate III.

shall assume for our back pressure, p_2 , 30. This problem bears the same relation the same values as were taken in Case III.

Tables IX. and X. contain a summary assume the most favorable practical con- in Metric and British units of the data ditions for the working of either of the fluids with the exception of water; hence, sponding theoretical indicator cards are

TABLE IX. DATA AND RESULTS FOR CASE V.

			METRIC	UNITS.				
Vapors.	$t_{_1}$	$t_{_2}$	$t_{_3}$	$t_{_4}$	$t_{\mathfrak{s}}$	$\tau_{_1}$	$ au_2$	$\tau_{_4}$
Water Alcohol. Ether. Carbon di-sulphide. Chloroform	172 172 172 172 172 172	90 70 50 60 60	40 40 40 40 40	145 145 145 145 145 145	120 120 120 120 120 120	445 445 445 445 445	363 343 323 333 333	418 418 418 418 418
Vapors.	$ au_{_{5}}$	$p_{_1}$	p_2	p_s	p_4	- p ₅	λ,	λ_{2}
Water	393 393 393 393 393	84,518 164,600 318,970 179,230 145,720	7,043 7,358 17,190 15,844 10,214	748 1,822 12,355 8,405 4,978	42,50 87,85 176,25 112,05 90,00	$egin{array}{c c} 29 & 43,953 \ 15 & 104,978 \ 70,026 \ \end{array}$	5 159 55.2 60.1	542 221 87.9 82.9 61.1
Vapors.	$\lambda_{_4}$	$\lambda_{\mathfrak{s}}$	К	$D_{_1}$	D_2	\mathbf{D}_{4}	D ₅	$v_{_2}$
Water	504.7 173.1 64.6 66.7 52.2	522.6 186.8 72.3 72.2 54.9	1 .966 .607 .257 .246	5.07 25.18 78.66 45.37 57.84	.467 1.28 4.97 4.63 14.69	2.63 13.87 44.82 29.26 36.85	1.29 7.16 27.50 18.90 22.50	9.37 18.59 18.53 8.25 12.23
Vapors.	v_4	v ₅	w	Н		E	F	M
Water	1.83 1.83 1.85 1.47 1.58	3.57 3.54 3.11 2.18 2.60	267,705 622,978 988,752 428,486 462,834	$ \begin{array}{c cccc} 3 & 2,894 \\ 2 & 4,447 \\ 3 & 1,798 \\ \end{array} $,904 ,823 3,275	20.12 % 21.52 % 22.23 % 23.83 % 23.12 %	5.19 11.07 21.78 28.98 34.21	1 .853 .535 .550 .761
			${ m T}_{ m ABL}$	E X.			•	

DATA AND RESULTS FOR CASE V. BRITISH UNITS.

Vapors.	$t_{_1}$	$t_{_2}$	$t_{_3}$	$t_{\scriptscriptstyle 4}$	$t_{\scriptscriptstyle 5}$	$ au_{_1}$	$ au_{_2}$	$ au_{_4}$.
Water	342 342 342	194 158 122 140 140	104 104 104 104 104	298 298 298 298 298	248 248 248 248 248 248	803 803 803 803 803	655 655 655 655 655	754 754 754 754 754

Vapors.	$ au_5$	p_{i}	p_2	p_{s}	p_*	p_{5}	$\lambda_{_1}$	$\lambda_{_{2}}$	
Water	709	17,310	1,442	153	8,705	4,153	869.4	975.6	
Alcohol	709	33,712	1,507	373	17,989	9,003	286.2	397 8	
Ether	$\frac{709}{709}$	65,328 36,708	$3,524 \\ 3,245$	2,526 $1,721$	$36,090 \\ 22,943$	$21,501 \\ 14,342$	$99.4 \\ 108.2$	158.1 141.2	
Carbon di-sulphide Chloroform	709	29,845	2,092	1,020	18,433	10,936	92.6	130.0	
Chiofolomic			,	2,010	,	,			
Vapors.	$\lambda_{_4}$	λ_{5}	K	D_{i}	D_{2}	$\mathrm{D}_{\scriptscriptstyle{4}}$	$D_{\mathfrak{s}}$	$v_{_2}$	
Water	908.5	940.7	1	.317	.029	.164	.081	9.37	
Alcohol	311.6	336.2	.966	1.572	.171	.866	.447	18.59	
Ether	116.3	130.1	.607	4.911	.903	2.798	1.717	18.53	
Carbon di-sulphide	120.1	130.0	.257	2.832	.623	1.827	1.180	- 8.25	
Chloroform	94.0	98.8	.246	3.611	.695	2.301	1.405	12.23	
							1		
Vapors.		v_4	v_5	W	Н	E	F	М	
Water		1.83	3.57	54,829	272,528	20_12 %	11.44	1	
Alcohol			3.54	127,592	592,904	21.52 %	24.40	.853	
Ether		1.85	3.11	202,506	910,954	22.23 %	48.02	. 535	
Carbon di-sulphide		1.47	2.18	87,758	368,310	23.83 %	63.88	.550	
Chloroform.		1.58	2.60	94,793	410.058	23.12 %	75.42	.761	

Conclusions.

31. From Case I., which is simply an illustration of a well-known law of thermodynamics, it may be seen that the theoretical effective work obtainable from a given quantity of heat is, when Carnot's cycle and the same limits of temperature are employed, independent of the working fluid. At the same time, however, the component parts of the total work may vary very much, as is illustrated by the figures in Tables I. and II., or, more clearly, by the indicator diagrams, Plate I.

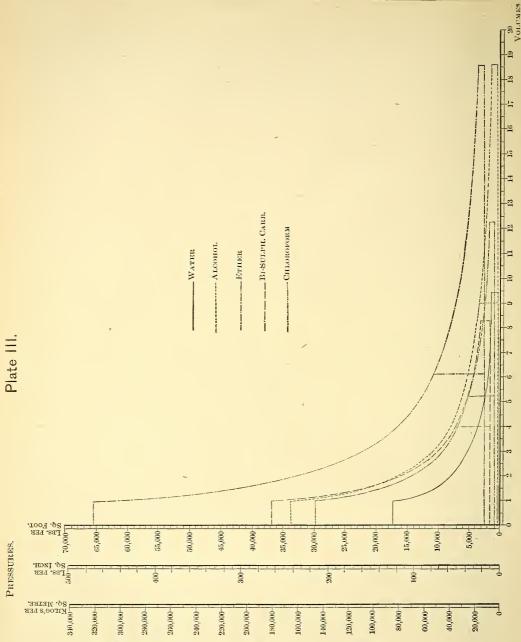
32. On comparing the efficiencies of the non-aqueous vapors in Case II. with the same quantities in Case III., we see that in every case, except that of ether, the figures are larger in the former than in the latter case. It would therefore seem, at first sight that the method we have taken of increasing the efficiency by reducing the ratio of expansion must fail. It must be remembered, however, that while, in the ideal case, expansion down to the back pressure is most efficient, there are certain practical considerations, such as condensation in the cyla more limited ratio of expansion best. to approximate in Case III., and hence advantages. the performance of engines built for

working these fluids would agree more nearly with the results of this case than with those of Case II. It is for this reason that we consider the results in Case III. of more practical value than those of the case preceding it; and it may be seen that, if we limit maximum pressure to that employed in the steam engine, steam is the most efficient fluid we can use. The relative size of cylinder necessary to produce the same power which is represented by the letter M in Tables III. and IV., is smaller for steam than it is for the non-aqueous vapors when all have the same initial pressure.

Case V. resembles Case III. in having the same final pressures, but differs in having higher initial pressures in all cases except that of steam. This higher initial pressure, involving higher initial temperature, and consequently greater range of temperature, causes such an increase of efficiency of the non-aqueous vapors as to put them all above that of water, and to cause some doubt as to which would be the best working fluid. judged thermodynamically only.

As the most convenient method of deinder and friction of engine, which make ciding the question just raised, we may compare each of the vapors with that of It is to this best ratio that we have tried water, showing their advantages and dis-

The vapor of alcohol gives us 1.4 per



cent. more efficiency than steam, and re-greater gain in efficiency (2.11 per cent.), quires a cylinder whose volume is only 0.853 of that of the steam cylinder to produce the same power. The disadvantages of alcohol are the high tension of the vapor, the great danger which arises from the ready inflammability of the hot gives a gain in efficiency of 3.71 per cent., liquid, and its cost.

and would require a still smaller cylinder (0.535 of that of steam), but it is open to the same objections as alcohol, and in a more marked degree.

The vapor of bi-sulphide of carbon and demands a cylinder 0.550 of that of The use of ether would give us a steam. It, however, is not only open to

all the objections that have been stated against alcohol and ether, but it has two which are peculiar to itself, viz., its intensely disagreeable odor, and its power of rapidly corroding iron which comes alternately into contact with it and with the air.

The vapor of chloroform, which gives a gain of 3 per cent. efficiency, and requires a cylinder 0.761, the volume of that of steam, is not open to the objection of inflammability, but it has so high a cost that it is probably impossible that it can ever be used economically in competition with steam.

All the apparent advantages of the non-aqueous vapors may be gained in the steam engine by an increase of initial pressure; and, as the tendency of modern practice is in that direction, it seems certain that none of the non-aqueous vapors will ever successfully compete with steam.

REPORTS OF ENGINEERING SOCIETIES.

A MERICAN SOCIETY OF CIVIL ENGINEERS.— October 1st, 1884.—Vice-President Wm. H. Paine in the chair. The following candidates were elected members: Burr Kellogg Field, Philadelphia, Pa; Charles Alfred Marshall, Johnstown, Pa.; Robert Imley Sloan, New York. N. Y.

Mr. H. Trueman Wood, Secretary of the Society of Arts, London, England, presented a short statement in reference to the International Inventions Exhibition, which it is proposed to hold in London during 1885. He expressed the desire of the management of the Exhibition that the engineers of America should know of this exhibition and aid in securing its success. It is one of the series of exhibitions which are in progress, that of last year being devoted to fisheries, and that of the present year to subjects connected with health and education. The Exhibition of 1885 will be devoted to apparatus, appliances, processes and products invented or brought into use since 1862. It is intended to illustrate industrial processes, and not to exhibit finished products unless required for full demonstration of a particular process. The Exhibition will be under the presidency of the Prince of Wales. The Chairman of the Executive Committee is Sir Frederick J. Bramwell, Vice-President Inst. C. E. Copies of a detailed prospectus were presented by Mr. Wood. The subject was referred to the Board of Direction for consideration.

The death on September 25th of Isaac Newton, M. Am. Soc. C. E., was announced.

Announcement was made that Messrs. L. B. Ward, E. B. Van Winkle and Amory Coffin had been appointed Censors to award the Norman Medal, and that Messrs. George S. Morison and D. Farrand Henry had been appointed on the committee to award the Rowland Prize.

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A paper by F. P. Stearns, M. Am. Soc. C. E., "Experiments on the Flow of Water through a 48-inch pipe," was read. These Experiments were made on a pipe on the line of the Sudbury Conduit, used to carry water across a valley. The pipe was cast-iron, coated with Dr. Angus Smith's coal tar preparation.

ENGINEERING NOTES.

MONSTER RUSSIAN BRIDGE.—It is reported from Russia that the question is being agitated of connecting Cronstadt and Oranienbaum by a bridge at a cost of £2,400,000. The structure is to rest upon granite pillars fixed by the caisson method, each of them protected from the action of the waves during the prevalence of south-west wind by an angular wall-like guard of stone. The bridge will be about five miles in length, and it is expected to be completed by 1889. When finished—if it is ever finished-it will consist of two parts, a railway and a foot-bridge.

The Severn Tunnel was begun in 1873 and is now approaching completion. It passed under the Severn where it is $2\frac{1}{4}$ miles wide. The length of the line is $7\frac{1}{2}$ miles, $4\frac{1}{3}$ miles being in the tunnel under the Severn. It is made almost wholly in rocks of trias and coal measure formation. The lowest part of the line is at 60 feet depth at low water, and 100 feet at high water. The work has been flooded on several occasions, much water being met with through-out the construction. The quantity of water now being pumped is about 19,000 gallons per minute. Other pumps are being erected which will enable 41,000 gallons to be pumped. The tunnel will be for a double line of way, and will be lined throughout with vitrified bricks set in Portland cement.

THE FORTH BRIDGE.—The contract for the bridge has been let for £1,600,000. The total length of the viaduct is about one mile and a half; the clear headway under the center is 150 feet above high water. Operations began in January 1883, and already about £370,000 have been expended. The main piers are all started; the minor and end piers are in an advanced state. For the superstructure the iron has been delivered. In one of the Fife piers the drilling of the rock had to be abandoned, a timber and clay coffer dam being constructed. The difficulty in the shallow rock foundation at the Forth much resembled Stephenson's when building the Victoria Bridge, the contractors treating it in much the same way. Forty-two miles of plates are required for the tubular compression. Finally the proper method was hit upon, consisting in bending plates hot, giving them a straightening squeeze afterwards No important modification has when cold. been made in the design. One change was made in attaching the superstructure to masonry, which consisted in securing it to one of four cylindrical piers in each group, and permitting a certain amount of sliding on others. The whole weight of the structure on the piers will cause friction between the surfaces of the upper and lower bed plates sufficient to prevent movement except in rare cases. Experiments have

proved that 56 pounds per square inch would be the highest wind pressure likely to be encountered.

IRON AND STEEL NOTES.

Tempering Steel by Compression. — We have repeatedly alluded to the A have repeatedly alluded to the method brought forward in France by Clemandot for tempering steel by compression. Further details have been furnished lately by a report by M. Ad. Carnot to the Societe d'Encouragement. M. Clemandot's method consists in heating the metal so that it becomes sufficiently ductile and then submitting it during cooling to a strong pressure. He noticed that this treatment affected the structure of the metal in such a way that it acquired properties analogous to those brought out by tempering. The metal thus obtained differs considerably from steel simply cooled, by its finer grain, its greater hardness, and its greater resistance to rupture, particularly with certain grades of pretty high carbon steel. In these respects it approaches in quality steel tempered in water, without being identical with it. It has two different effects, almost simultaneously, an energetic and continuous compression, and a rapid cooling of the steel. The cooling is caused by the contact with the platform of the hydraulic press, and takes place much more rapidly than when the same piece is allowed to cool without being compressed. The remarkable results obtained by M. Clemandot are explained by the combined action of cooling and compression. The first, in its results, resembles the compression effected by hammering or rolling; the second, the effect of tempering by immersion. It has been urged that the piece of steel must be inclosed by a mold into which it fits exactly. It is, however, only necessary that the compression act upon two opposite faces. A square bar, whether straight, or curved to horse-shoe shape, need only be laid down flat and compressed between the two platforms of an hydraulic press. In order to obtain the best results, the cherry-hot piece of steel should be as rapidly as possible subjected to the pressure settled upon beforehand, ranging from 10 to 30 kilograms per square millimeter.

While the tempering process by immersion brings about an increase in the volume of the steel and a corresponding decrease in its density, the action of high mechanical pressure during the entire process of cooling tends to bring the metal back to its original volume or its normal density, thus preventing the creation of a state of intermolecular tension noted in tempered steel. Actual experiment has confirmed these theoretical deductions, so far as the resistance of the compressed steel to stress is concerned.

RAILWAY NOTES.

MPROVEMENTS IN THE PERMANENT WAY AND WORKS OF ITALIAN RAILWAYS—By F. BIGLIA.—This paper contains the results of the second of the three commissions upon matters relating to the Italian railways. The Berne International Conference, recommended that the

international gauge should be changed from 4 ft. 8.5 in. to 4 ft. 8.69 in. This was objected to by the French and Italian delegates, because in France many of the principal lines have a gauge of 4 feet 9.08 inches, and in Italy the gauge is fixed at 4 feet 8.89 inches, a mean between the French of 4 feet 9.08 inches, and the German of 4 feet 8.5 inches. The Italian Commission agreed to accept the gauge proposed at Berne as soon as it should be adopted by the French Government.

Foot Signals at Points.—The commission decided that these are not to be considered as stopping signals, their object being to enable the station-men to see from a distance how the points stand, and to show the engine-driver upon what line he is traveling. There was a long discussion as to the color to be adopted for these, a red ought to be used exclusively for stop signals, but nothing was decided. These signals are to be limited to the points at the ends of stations, and to those giving access to large groups of good sidings.

Level-crossing Barriers worked from a distance. -The following are the decisions of the Commission in regard to these. A bell is to be fixed near each barrier, and rung before it is moved, to give notice to travelers. Barriers must be visible from the points at which they are worked, which must not be at a greater distance than 1,600 feet. Lights are not to be provided, except in special places. One man is not to have more than two distant barriers under his charge, in addition to his own gate, and the levers must be within 32 feet of each other. The barriers are to be placed parallel to the line, at a distance of 6 feet 6 inches from the nearest rail; there is to be a separate lever for each side of the line, and the barriers are to be constructed so that they cannot be opened and shut by passers by. They are to be weighted so as to close gradually in the event of the connection with the lever breaking. The use of these barriers is to be confined to unimportant roads and to single lines of railway upon which the traffic receipts are less than 35,000 lire per kilometer per annum.

Three-throw Points—It was decided to allow these to be used, but not upon lines traversed by express trains; the central line must be straight. They may also be used on express lines at stations where all trains stop. A system of double points, by means of which trains running in either direction upon either of two lines of way, can either keep their own line or be shunted on to the other, is permitted to be used in certain cases, but limited to slow lines and sidings.

Attachment of Trolleys to Trains.—One of the questions discussed was whether trolleys might be attached to trains by slip-couplings. It was objected that the attachment being necessarily above the center of gravity of the trolley, there is a tendency to turn it in a vertical plane round the front axle whenever this encounters the slightest resistance. On the other hand the plan is most useful for drawing heavy loads up steep inclines, for when the workmen have to push the trolleys themselves, they arrive at the place where they are going to work exhausted, and, which is worse, in a state of heat which exposes them to attacks of fever in unbealthy

districts. The Commission decided to allow the attachment to slow trains on lines having

gradients steeper than 1 in 100.

Traffic at Level Crossings.—On the Italian lines there is generally a level crossing at each station, and as these are situated in populous places, they are the occasion of constant complaints from the inhabitants, owing to the length of time during which the gates are closed, either ou account of the trains being late or during shunting operations. There are also frequent . crossings in the open country. If it is proposed to substitute a bridge for a crossing, the necessary approach is objected to, especially in level districts, when the necessary gradient would limit the load which animals can draw. Besides this, owing to the station-sidings it would often be necessary to carry the road across the line at some distance from the station, and this would necessitate a long diversion. The time during which the gates are closed can be limited by the use of signals, but, on the other hand, it is impossible to run quick trains when the driver has always to be ready to stop at these signals. After some discussion, the Commission decided (1st) that iu order to insure sufficient protection of level crossings at which it is important to limit the time of closing the gates as much as possible, they might be entered in the time-tables and treated like stations, and provided with disk signals and electric instruments to give notice when the trains are late; (2d) that at less important crossings it will be sufficient to provide telegraph communication with the nearest station; (3d) that ou maiu roads crossing lines of heavy traffic, especially where the roads have steam trams on them, it is essential that bridges over or under the railway should be built, and, considering the interests involved, the cost may be divided between the railway and the public bodies which would benefit by the change. It must not be forgotten that the cost of gate-keepers will be saved.

Ballast.—Ever since the construction of railways was commenced it has been a disputed point whether the ballast should cover the sleepers or be laid level with their upper surface; the former system protects the timber from the direct rays of the sun, from sudden changes of temperature, from moisture, dryness, and frost, and gives excellent results in preserving the sleepers from decay. These advantages are, however, denied by some engineers, who consider that covering the sleepers makes them decay more rapidly, and increases the first cost of the line and the difficulties of

maintenance.

The Commission came to the conclusion that though uncovered sleepers may be preferable in northern climates, it is necessary iu Italy to

completely imbed them in the ballast.

Working strains allowed in Iron Roofs and Cranes.—The working strain allowed in bridges in Italy is 3.81 tons per square inch, provided that the breaking-straiu is not less than 20.32 tons, and the limit of elasticity 9.52 tons per square inch. Italy being entirely dependent upou foreigners for supplies of iron, it is found more economical to use Belgian iron, which will stand these tests, rather than stronger but Sons.

more expensive material. For roofs the Commission fixed upon working-strain, 5.08 tons; breaking-strain, 22.86 tons per square inch, with 8 per cent. extension. Various methods have been suggested for limiting the weights lifted by cranes, among others Hohenegger's apparatus, which indicates the weight which is being lifted, and automatically prevents the lifting of weight in excess of that which the crane is designed to carry. The Commission determined to conduct trials with this apparatus.

There is annexed to the Paper a report upon lighting carriages with oil lamps.—Abstracts of the Institution of Civil Engineers.

ORDNANCE AND NAVAL.

E-ARMING THE NAVY.—About 400 of the new steel guns have been completed at the Royal Gun Factories, and these are nearly sufficient for the re-armament of the smaller ships of the Royal Navy. More than 150 of the new guus are of the 6-inch class of breechloaders, and seven-eighths of the whole are especially adapted for sea service. Large guns for the heavier ironclads are now in course of construction and all the guns now made being of the type described by Colonel Maitland in his recent lecture as the latest combination of all that is best in all the best systems, it is hoped that within a year or two the present deficiencies in the armament of the Royal Navy will be satisfactorily repaired.—The Engineer.

ORPEDO EXPERIMENTS IN BANTRY BAY.— Two experiments with fully charged Whitehead torpedoes have been made by two vessels of the Channel Squadrou at Bautry Bay. The steam pinnace of the Minotaur discharged a Whitehead torpedo at a large rock at the head of the bay. The machine ran at a rate of 13 knots an hour, being loaded with a charge of 117 lbs. of gun-cotton. It was adjusted to run 117 lbs. of gun-cotton. It was augusted 400 yards, and was discharged when the pintorpedo, a 16-inch one, weighed 600 lbs. It struck the face of the rock 7 feet from the surface and threw up about 30 tons of water to a height of 300 feet, also several pieces of rock. The result of the experiment was considered most satisfactory, the more so as the rock was very unfavorable for the purpose, containing a number of crevices and presenting no even surface such as a ship would. The base of the rock was nearly destroyed, large pieces being disconnected. The second experiment, conducted by the Neptuue, was not successful; the machine did not go fair and missed. It ran its full course of 400 yards and sank. During the stay of the fleet numbers of successful experimeuts have been conducted with submarine mines and stationary torpedoes.

BOOK NOTICES.

Publications Received.

INTERNATIONAL Health Exhibition Library Catalogue. London: William Clowes &

Monthly Weather Review for August. Washington: Government Printing Office.

Papers of the Institution of Civil Engi-

neers:

No. 1892.—The Ashti Tank. By Charles

Toler Burke, M. Inst. C. E.

No. 1985.—On Galvanic Action Between the Various Irons and Steels in Sea Water. Thomas Andrews, F. R. S. E.; Assoc. M.I.C.E.

No. 2014.—Water Supply in Peru and Distilling Apparatus at Iquique. By Charles Malcolm Johnson, R. N.; Assoc. M. I. C. E.

Abstracts of Papers in Foreign Transactions

and Periodicals.

No. 2008.—The New Harbor of Trieste. By Friedrich Bornches

No. 2015.—Old Water Supply of Seville. By

George Higgin, M. I. C. E.
No. 2010.—The Area of Sluice Opening for Tidal Canal. By James Henry Apjohn, M. I. C. E.

No. 1972.—The Passage of Upland Water through a Tidal Estuary. By R. W. Peregrine

Birch, M. I. C. E.

No. 1964.—A Dioptric System of Uniform Distribution of Light. By Alexander Pelhorn Trotter, Assoc. M. I. C. E. No. 2000.—Wood Pavement in the Metropo-

By George Henry Stayton, Assoc. M.I.C.E. London: Published by the Institution.

TREATISE ON STEAM-BOILER INCRUSTATION.
By CHARLES THOMAS DAVIS. Washing-

ton: Industrial Publishing Co.

There is no doubt of the importance of the subject of this practical treatise. The author has endeavored to furnish "reliable information as to the various compounds and mechanical apparatus employed for the prevention of boiler incrustation," and has achieved a fair success. The book presents but little improvement upon former works on the same subject, Rowan's for example, so far as explaining the causes and cure of the evil are concerned, but is much fuller in its description aided by diagrams of different methods.

On the other hand, the author rests content with mere enumeration and brief description of the various processes. Of their relative efficiency the reader is left to draw his own in-

ference.

Treatise on Ore Deposits. By J. Arthur A PHILLIPS, F. R. S. London: Macmillan & Co.

That this treatise will be accepted as a standard authority may be safely assumed. The previous works of the author have earned for him the reputation of a careful and industrious contributor to the literature of metalliferous deposits. His "Manual of Metallurgy," and "The Mining and Metallurgy of Gold and Silver," are well-known books of reference in all libraries of general technical literature.

The first part of the new treatise is devoted to "ore deposits in general." This part may be read with profit by students of geology who have no interest in hunting ores. The various ways in which the accumulations of valuable metallic compounds have been brought about are discussed and fully illustrated by dia-

grams.

Beginning with superficial deposits, the author describes their accumulation under the mechanical action of water and the chemical reaction which has caused precipitation out of solutions.

The origin of Stratified Deposits is next con sidered, and the theories of precipitation with or without subsequent metamorphism, are clearly set forth. The dissemination through sedimentary beds receives its full share of at-

The next section, Unstratified Deposits, would of itself make a valuable handy book for the mining engineer. It is devoted to the description of the so-called mineral "veins" of all kinds. In succession are presented Modes of Occurrence of True Veins, Intersections and Faults, Structure and Composition, Distribution of Ores in Lodes, Out-crop of Lodes, Grouping and Sequence of Minerals in Lodes, Influence of Depth, Influence of Country Rock, Age of Mineral Veins, Genesis of Mineral Veins, Theories respecting the Formation of Mineral Veins, Segregated Veins, Gash Veins, Impregnations, Contact Deposits, Fahlbands, Cham-Diagrams are abundant bers or Pockets. throughout.

Part Second describes the "Ore Deposits of the Principal Mining Regions," and is divided into shorter sections each of which deals with the mines of a country. In addition to the geological and physical features of the mining regions there is added in many cases the his tory of the earlier operations and the statistics of the later ones. It is not often that a book bearing a title suggesting only a technical value contains so much varied and in every

way valuable information.

TREATISE ON CHEMISTRY. By H. E. ROSCOE, F. R. S., and C. Schorleunner, F. R. S. Vol. III., Part II., 8vo, cloth, New York: D.

Appleton & Co.

The second part of the volume on Organic Chemistry of the work which has been described as "the finest systematic treatise on modern

chemistry," has just been published.

New discoveries are continually extending the confines of organic chemistry. A few years ago, all that was known concerning it could be summed up in a few brief paragraphs, but the magnificent discoveries in the department of dyes, the wonderful development of synthetical chemistry have led to increased activity in this branch of chemical science, so that to-day a description of its compounds requires a space equal to, if not greater than, that of mineral chemistry.

A full review of the contents of this book cannot be attempted here. A few remarks on this point, however, will not be out of place. Among the uric acid compounds, descriptions of caffcine and theobromine will be found. The similarity of their composition to that of certain of these bodies suggests that the preparation of these so-commonly used alkaloids from guano,

may be possible.

Glycerot, generally called glycerine, is fully described. Its preparation, its properties, its derivatives (including nitro-glycerine), and its applications are thoroughly discussed. We find

that when "it is allowed to stand in a sufficiently concentrated condition at 0° C. (32° F.), crystals form after some days." Its boiling point is stated to be 290° C. (554° F.)* The carbo hydrates are treated quite fully, cane sugar naturally receiving most of the attention. Grape sugar is not neglected, but sorghum sugar receives scant justice and is dismissed with a paragraph. With cellulose, its explosive derivative gun-cotton, collodion also, and the details of paper-making come in for considera-

For the benefit of those who desire more detailed information, foot notes containing references to original memoirs are given on nearly every page. Clear, beautiful illustrations, engraved especially for this work, are inserted

where necessary.

In 1877, nearly eight years ago, the first of this series appeared, and the present volume, completing the work, fully sustains the promise

of that initial portion.

The distinguished authors, Prof. H. E. Roscoe and Prof. C. Schorleunner, of Owens' College, Victoria University, Manchester, England, deserve our thanks and congratulations for having brought to a successful termination so beautiful and perfect a work on chemistry.

It is not excelled by any similar treatise in

the English language.

THE ATTAOK AND DEFENOE OF COAST FOR-TIFICATION. By CAPTAIN EDWARD MA-GUIRE, Corps of Engineers of the U. S. Army. Published by D. Van Nostrand, 23 Murray Street, New York City.

From the earliest times the problem of the defence of its coast has occupied the attention of every nation having a border on the sea. In every country the seaboard towns are the main sources of the nation's wealth. Consequently the defence of these towns from destruction or occupation by an enemy is a matter of interest to every inhabitant who has anything at stake, whether it be dollars or whether it be national pride. The whole history of the attack and defence of coasts is but a record of progress and development; progress in the art and science of war and development of the applied means of attack and defence. close of the war of the rebellion found the United States the best fortified country in the world with the finest forts and the best guns. But the long and valuable experience of that war led to much scientific study of both ships and forts. The European nations have devoted much time and money to the problem of gunsafloat and guns-ashore. During the many years of costly experiments guns grew in size and power, and ships' armor increased in might and strength, and at the present time we have huge armored floating citadels like the Italian "Duilio." But ships must manœuvre and for that purpose they must possess certain very essential qualities—flotation, stability and sailing capacity. These qualities put a limit in the size of the ship and hence on the weight of its armor and armament. That limit has been reached, and to-day the problem of the attack and defence of coast-fortifications is susceptible

of solution and the principles upon which that solution depends are simple in character and of The little book now before us application. aims at an exposition of these principles. It treats of naval fighting means, giving a description of the different kinds of war-ships, as well as discussing the operations of a fleet against coast-fortifications; it devotes much attention to coast-forts and batteries; obstructions and sca mines; accessory defences, the armament of batteries; the general measures of coast defence, and closes with an example of modern coast-defence. It contains many illustrations. The writings of the great European nations as well as of our own have been called upon by the author for material for his work. originally commenced as a series of professional notes he has developed into a book. The introduction gives an insight into the author's object in publishing the work. It reads as follows:

As a rule the periodical military literature, as well as the text-books, treat the above mentioned subjects only by piece-meal, and usually only with reference to secure particular work which the author at the time has on hand. Under such circumstances one is forced to wade through a great mass of material in order to garner that which is worth knowing. This is a tedious and often impracticable process. Books are expensive, professional libraries scarce; and a knowledge of French and German, at least,

is almost indispensable to the student.

"Again: a great many of the text books go too much into the details of old forms, and devote too much attention to dead issues. The tendency is to force the young man to spend part of his life in a past age; that is, to encumber his mind with a mass of information which even his grandsire would have been glad to have

There has of late years grown up the idea that torpedoes alone will constitute a sufficient

forgotten.

defence for this country. Congressmen make long speeches in favor of torpedoes and refuse to vote an appropriation for forts and guns. Even some professional soldiers have been carried away with the defence of our harbors by means of submarine mines alone. The very uncanniness of the torpedo and the general ignorance of the masses of the true nature of submarine mines has invested them with a species of awe and admiration. The author of the book is an advocate of forts and big guns and closes his discussion of submarine mines as follows:

"Submarine mines can in no case replace guns, especially as their own security depends upon guns. Guns and passive obstructions may constitute an effective defence, but submarine mines alone—never. It must be distinctly borne in mind that a submarine mine has but one life, and, having been once exploded in action, it cannot be replaced: while the activity of the guns is limited only by the supply of

ammunition.

"Submarine mines, more than any other weapon, call for experience, skill, training, and the closest attention on the part of those operating them. From the very nature of things they must be operated by "the few;" while guns can be fought by "the multitude," and without

^{*} See p. 173, August, 1884, issue of this magazine.

very great training. It is a well-established principle that all engines-of-war should be as little complicated as possible, and as free as possible from delicate parts; therefore the main defence should never be left to submarine mines, which any one of a number of unforeseen accidents may render useless, and which can be operated by only a few men whom it would be difficult to replace in time of action."

While the book is written especially for the professional soldier it should not be without interest for every thinking citizen. There is very little of the purely technical in it, and as a whole it is easy of comprehension. The publishers have done their work well. The volume is a handsome one, clearly printed, and elegantly bound.—Commercial Advertiser, Buffalo.

PRACTICAL TREATISE ON ELECTRIC LIGHT-A ING. By J. E. H. Gordon, B. A., M. S. T. E., etc. New York: D. 1884. pp. 228. Price \$4.50. New York: D. Appleton & Co.

This book is from a pen which has already achieved a reputation by the production of an excellent treatise on "Electricity and Magnetism," doubtless known to many of our readers. In his first work, however, the author wrote from the standpoint of the physicist, while in the present work he writes rather from the stand-point of the inventor. This change of the author's position relatively to his theme is, as might be anticipated, detrimental to the book

to a great extent.

It is undeniably to the credit, as much as we trust it may be to the profit, of the author to have sought to lend a hand in the practical development of the art of electric lighting. But in turning inventor he has placed himself in such a relation to this art that his judgment must inevitably suffer from the changed per-spective. He is no longer sufficiently removed from the whole field to be able to see things as "outsiders" see them. What is immediately near him seems to grow in size, while everything else fades into insignificance. The partiality of the author to his own or his friends' methods would not be so objectionable were it separable from a certain indifference and prejudice which obscure or ignore the methods of others.

The book is divided into twenty-one chapters, but one of these (Chapter XIX.—"Central Station Lighting") is merely laid out, the five lines under this head being intended as a prospectus of a "long chapter" which is to be inserted there in a future edition, the author not being prepared, "for various reasons," to write it for the present edition. We venture to say that if there had been any central station on the "Gordon" plan to describe, one of these various reasons at least would have been re-As for what has been done by Edison in central station lighting by incandescence, and by Brush and others in arc lighting, it was probably not worth mention.

Of the twenty filled chapters, about ten are extremely good, and the rest as extremely bad. The good chapters are those in which the principles underlying the art of electric lighting are analyzed and elucidated. In these chapters

has an axe of his own to grind. We think so well of these portions of the work that we regret that the author did not publish them separately with the excellent tables contained in the appendix, and, by so doing, give us a most excellent treatise on "The Principles of Electric-Light Engineering." Chapter I. (Principles of Artificial Lighting), Chapter II. (Conversion of Electric Currents into Heat), Chapter III. (Electrical Units, Heat, Work, etc.), and Chapter IV. (Rules for the Resistance of Divided Circuits) fulfill their respective missions in a very creditable manner, making intelligible much that has failed to become plain in the hands of other writers. We might say the same of Chapter IX. (Magnets and Electro-Magnetic Induction) and Chapter X. (General Principles of Electrical Generators), and also of Chapter XVII., though in this case the author has sacrificed much of the clearness for the sake of brevity. Chapter VIII. (Carbons for Arc Lamps) is one of the most interesting and valuable in the book, especially so since there is little said in other books on this subject. Chapter XI. (On Designing Dynamos, and on their Mechanical Construction) is that to which we feel disposed to award the palm for excellence. We believe that to many this chapter alone will be worth the price of the book, for it gives many practical hints and methods, and, above all, it teaches common sense. If we add to these Chapter XXI., which is merely a reprint of the "Rules for the Prevention of Fire Risks," drawn by the Society of Telegraph Engineers, and the Appendix, which contains a number of very useful tables, we shall have mentioned about all that can pass without adverse criticism. The chapters not yet named are those which are wholly or mainly descriptive, and they all suffer from the illusion of perspective which we have explained above. We fear that the unwary student will often get from these chapters impressions and prejudices that were better What concerns Mr. Gordon or his avoided. friends is very fully described, even to obsolete forms and to minute details. As for other inventors and inventions, they are either ignored altogether, or else passed over with descriptions too meager, too careless, we might say, to be reliable and useful.

In Chapter V. there is not even a mention of the Deprez-Carpentier current meters, after which were patterned those of Ayrton & Perry, which are so fully described. In Chapter VI. the lamp most extensively used the world over —the Edison lamp—receives the least attention, namely, one page with one illustration, which follow some ten pages, including fifteen plates and illustrations, devoted to the "evolution" of the Swan lamp. In Chapter VII. the author shows his deference for his friend, Mr. R. E. Crompton, by telling all he can about his lamp, and as little as possible about any others. Four forms of Crompton arc lamps are described at length, with numerous figures, and only two other lamps, the Serrin and the Brush, are referred to. Chapter XII. (Some Typical Alternating Current Machines) contains a "reference" to the machines of De Meritens and Siemens et al. (South Proposed Control of the Propo mens, a "criticism" of the Farranti machine, there is no evidence, at least, that the author and a "description" of the Gordon dynamo.

Chapter XIII. (Some Typical Direct-Current Machines) begins with a full description of the Crompton-Burgin machine, after which come rather inadequate descriptions of the Brush-Siemens and "large" Edison machines. The author doubtless imagines he has given his readers "a representative selection," for he says in the preface: "In describing machines and lamps I have not thought it necessary to describe many, but have selected those which are typical of different classes." Chapter XIV. (Regulation of Machine) is evidently intended to force a conclusion, and this conclusion is printed in italics at the end of the chapter. Briefly, this conclusion is: The true secret of successful regulation is Mr. Gordon's own plan. Mr. Gordon's plan of regulation does not contemplate by compound winding, and of course he "doubts if compound winding, in spite of its apparent simplicity will be much used in the future, except for small machines!"

Mr. Gordon sees no earthly use in storage batteries, and Chapter XVI. is devoted to the proof of that doctrine. These details are sufficient to show that the descriptive portions of this book are to be taken with a rather large grain of allowance for the author's partiality and prejudices—a personal equation which undoubtedly would not appear if the author were not identified with the art as an inventor. for the rest of the book, it is, as we have said already, most excellent, and it will perhaps bring the book into favor in spite of the faults

we have just noted.

THE THEORY OF DEFLECTIONS AND OF LATITUDES AND DEPLETATIONS AND DEPLETATIONS AND DEPLETATIONS AND OF LATITUDES AND DEPLETATIONS AND DEPLETATIO TUDES AND DEPARTURES—WITH SPECIAL APPLICATION TO CURVILINEAR SURVEYS FOR ALIGNMENTS OF RAILWAY TRACKS. By ISAAO W. SMITH, C. E. 16 mo., morocco tucks. Price, \$3.00.

Geometer is the Greek word for a land surveyor or measurer, and, at the present time, geometry would seem to be all Greek to a large portion of such geometers. Chiefly because of the false definitions of quantities given in the text books used in schools and colleges, on account of which graduates in mathematical courses, on attempting to reduce their theories to practice ou any other than a paper field, are confronted with quantities of which they have had no previous knowledge, and are unable to solve the simplest problems beyond the compu. tation of the sides and angles of a triangle.

It is claimed by authorities in geometric science that their conclusions are based on definitions easily understood, and on self evident axioms and postulates, but any one of ordinary common sense, who will trust to his own judgment and not be overawed by the weight of authority, will find by examination that their premises are often in direct opposition to their

conclusions.

An angle, for iustance, is defined by Euclid (see Playfair's translation), as "the inclinatiou between two straight lines which meet and are not in the same straight line;" by Legendre as "the quantity, whether greater or less, by which two straight lines which meet depart from each other as to their positions," and by Davies as "the space, or the divergence, between two straight lines produced to intersection;" and from text books.

these widely different definitions, as a relation between two straight lines which are not in the same straight line, they each deduce the same elementary proposition, that the lines are in the same straight line when the angle is 180 degrees.

From these definitions it will therefore follow that the inclination, or the departure, or the space, or the divergence, between two lines is twice as great when they are portions of the same straight line as when they are perpendic-

ular, or at an angle of 90 degrees.

This absurd couclusion, that the angle between two straight lines comes into existence only when they are produced to intersection, has been the source of countless blunders and much useless waste of money, especially on railway surveys, on which it is necessary to calculate the sign and magnitude of each tangential de-

flection on the alignment.

In proof of this might be cited a circular issued by the chief engineer of an important transcontinental road, instructing his assistant engineers to produce always to intersection tangent lines from the extremities of each circular arc; nor is this in any way a singular instance of supermathematical stupidity. Iu a work for instance, on the elements of plane surveying and navigation, by the late Mr. Davies, professor of mathematics in the United States Military Academy of West Point, after defining an angle as the portion of a plane between two straight lines which meet at a common point, he gives four elaborate rules for determining the angle between two straight liues from their bearings and adds, in a note, that "the above principles are determined under the supposition that the two courses are both ruu from the same angular point, hence, if it is required to apply them to two courses run in the ordinary way, as we go around the field, the bearing of one of them must be reversed before the calculation is made."

In application of these rules it is theu stated that, when the bearings of two courses are N 39 W and S 48 W, the angle between them is 93 degrees when measured from the same angular point, and 87 degrees as "we go around the field." The same confusion of ideas exists as to the natures of other trigonometric quan-

A ship sails 100 miles in a direction 30 degrees right or left of a north direction; the departure at right angles to a north line, is a half mile to the mile, and has the same sine with the bearing, and this rate of departure, equal to five tenths, is the sine of the bearing, and the departure in 100 miles is 100 times the sine of 30 degrees and equal to 50 miles.

But turning to Legendre it will be found that the sine is the perpendicular let-fall from one extremity of au arc upon a radius through the other extremity, and hence it would follow that a sine is not a constaut quantity, but varies with the radius of the arc by means of which

it is measured.

Plane trigonometry, or the problem most frequently recurring in plane trigouometry, is the determination of the relative positions of points, or the direction and distauce from one point to auother, and it is singular that direction is seldom or never considered or even alluded to in

A direction may be defined either as from one known point to another, or by the bearing or deflection, right or left, from some known direction. The relative position of two points may also be defined by the difference of their co-ordinate distances from two axes of known directions or, when the axes are rectangular, by the differences of their latitudes and departures.

The deflection from any direction to the same direction again is equal to 360 degrees; if the deflection from a direction BA to a direction B C is 180 degrees, A, B and C are on the same straight lines; the total deflection from one direction to another is the algebraic sum of the partial turns made in making the deflection; the departure of a line is the perpendicular distance, right or left, to the terminal point from an axis of given direction through its initial point; the sine of the bearing from the given axis is the rate of departure, and the sign of the sine and departure is the same with that of the bearing; the departure of the closing line from the initial to the closing point of a series of lines is the algebraic sum of the departures of the several lines composing the series. This is a brief summary of the principles of plane trigonometry, and the quantities are the same by the rough calculation of which the hunter or explorer can approximately determine the direction and length of the closing line from his starting point.

The theory of latitudes and departures has been long in use in plane surveying and navigation, but the theory of deflections, although applied to some extent on railway surveys, has not been reduced to a mathematical system. The object of the work is the application of these theories to the solution of problems in curvilinear surveys for alignments of railroad tracks, and it contains, besides the strictly mathematical propositions, the solution of all classes of problems generally presented in such works, and of many which, although of constant application, have hitherto been solved by the process known among surveyors as fudging.

Many of the propositions are not new, but they are derived by an original process, and based on the true nature of trigonometric quantities, and are an extensive experience in all classes of surveys in the Eastern States; in Mexico, and on the Western Coast, in the service of the Northern, Southern, Central, and Oregon Pacific railroads, in yard work and in the several capacities of leveler, transitman, assistant, Division and Chief Engineer, and on reconnoissances, preliminary and location surveys, as well as on construction.

Surveying does not require a high order of engineering talent, but what must be done should be well done, and few can realize the great and useless expenditures by men who can compute without understanding the quantities computed, or who understand their quantities without the ability to compute.

MISCELLANEOUS.

Jacquelain has endeavored to procure a pure carbon for electric purposes that should be as hard and as conductive as gas carbon. He first takes gas carbon, which he submits to four processes: (1) Treatment with dry Dingler's Journal.

chlorine at a red heat for thirty hours; (2) treatment with hot alkali for about three hours; (3) immersion in hydrofluoric acid—one to two of water—at a temperature of 15 deg. to 25 deg.; (4) carbonized by heating strongly in the vapor of a high boiling hydrocarbon, for commercial purposes gas tar will do well. All these operations may be performed after the carbon has been cut into sticks. By these processes, which do not seem to be new in any particular, the *Scientific American* says, the impurities have been reduced to a minimum, and a good, pure carbon is obtained.

N THE PRESERVATION AND USE OF BEECH-WOOD FOR RAILWAY SLEEPERS.—By CLAUS. The use of railway sleepers of beechwood has hitherto been very limited. In Germany only about 1 per cent. of the sleepers is of this wood, and in Austria 3 per cent., although large beech forests are available in both countries. The slight durability of ordinary beech sleepers is the chief reason of this; their life is reckoned at two and a half to three years, while oak will last fourteen to sixteen, and fir seven to eight years. The best method of preserving beech sleepers appears to be impregnation with creosote. Prepared in this way the average durability of the wood for railway purposes appears to be about eighteen years, while chloride of zinc only preserves it for fifteen years. Sleepers impregnated with sulphate of copper or sulphate of barium had to be replaced after four or five years. In many places the expense of impregnated beech-wood is so much less than that of oak, that it might be used with great advantage were it not for the peculiar manner in which some beech sleepers have been observed to give way under sudden strain. In such cases the exterior of the wood appears perfectly sound, while the heart has become rotten and affords no hold for spikes or bolts.

In France the proportion of beech sleepers is much larger than in Germany; they are chiefly impregnated by Blyth's method, by which each sleeper absorbs about 22 lbs. oil of tar, while in Germany 36 lbs. of creosote are injected. The French method does not appear to remove the organic matters, which are liable to decomposition.

In Germany Rutger's method is in use for preparing these sleepers. They are gradually raised to a temperature of 130° Centigrade, and dried for at least four hours, until they cease to give off vapor and are completely warmed throughout. They are then removed, on the same trucks upon which they have been dried, to the creosoting apparatus. This consists of a horizontal cylinder with hermetically closed doors in which a partial vacuum is produced and maintained for half an hour. The warm creosote is then allowed to enter the cylinder, and the whole is subjected to a pressure of 100 lbs. per square inch for one hour. Before injecting the creosote it is advisable to extract by boiling so much of the sap from the timber as is possible. This should be done while the wood is new and before the sap has begun to ferment. After this operation the sleepers must be allowed to dry for two or three months. Beechwood prepared in the above manner appears to be well suited for railway sleepers.—

VAN NOSTRAND'S

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THEORY OF THE SLIDING FRICTION OF ROTATION.

BY ROBERT H. THURSTON, HOBOKEN, N. J.

From Transactions of the American Society of Mechanical Engineers.

ism gives rise to losses of energy and to increase of resistance which are usually very considerable, and which are often the only sources of "lost work," and of the reduction of efficiency below its maximum value—unity. In any wellproportioned and properly managed machine or train of mechanism, the wastes of energy are due solely to friction; in badly-proportioned mechanism, subject to overstrain or shock, causing deformation of parts, energy is lost equal in amount to the work expended in producing permanent distortion. But as the engineer generally only considers cases of correct construction in determining the magnitude of such waste, it may be asserted, as a general and fundamental principle, that, in all good engineering, the sole cause of waste of mechanical energy is friction. These facts and this principle sufficiently indicate the importance to the engineer of a careful study of the magnitude and of the method of such

The writer has elsewhere* given the results of experimental determinations of the values of the coefficients of sliding friction, and has shown that the lost work in mechanism varies very greatly in

SLIDING friction in systems of mechangives rise to losses of energy and to crease of resistance which are usually ry considerable, and which are often e only sources of "lost work," and of e reduction of efficiency below its aximum value—unity. In any well-oportioned and properly managed materials amount; that it is, under favorable circumstances, vastly less than has been generally supposed; and that it is influenced, where lubrication is employed, by every change of velocity of rubbing, of temperature, and of intensity of pressure, as well as by the character of the lubricant.

In machinery and mill-work, and in mechanism generally, it is usually found that the wastes of energy caused by sliding friction are principally due to friction of rotation; i. e., to the friction of shafting, of journals, and of pivots in their bearings. This form of friction, and this method of waste, are the subjects of the paper here presented. The friction of straight sliding pieces has been frequently studied and is well understood; that of rotation has been less fully investigated, although considered at some length in a few treatises. The importance of the subject is such, however, as will justify the most extended examination.

THE FRICTION OF JOURNALS causes a waste of the energy traversing a machine, which is dependent in amount upon the velocity of rubbing, the magnitude of the load, the method of distribution of the resulting pressure, and of variation of its intensity, the size of the journal, the nature of the lubricant and its physical condition, especially as determined by its

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^{*} Friction and Lubrication, Railroad Gazette Publishing Company, New York, 1878 Materials of Engineering, Part I., 2d Edition, J. Wiley & Sons, New York, 1884.

efficient of friction as determined by all

these modifying conditions.

A journal in good order, well-fitted, and smoothed down by prolonged working, should never show evidences of Such journals have measurable wear. sometimes been known, by the writer, to show no appreciable alteration of form and fit after years of constant work.

The First Case of permanent fit of journal is that in which the journal is exactly fitted to its bearing when new, and so perfectly adjusted that no sensible wear takes place. In this case, the pressure brought upon the rubbing surface by the load is distributed by a certain method of yielding of the loaded metal, and according to a simple and definite law, the investigation of which is one of the principal objects of this paper. der this law, an adjustment takes place which, if the bearing surfaces are sufficiently large, of good material, and well lubricated, is permanent.

The Second Case is that in which wear occurs, and until all parts of the journal and bearing in contact wear until a "fit" is thus attained, such that every part is compelled to carry equal pressure, and until wear ceases to be observable.

The Third Case to be considered is that in which the journal is loose and the bearing surface, or surface of actual contact, is assumed to be a straight band of inconsiderable width.

These are the three typical cases for cylindrical journals, and these cases only are to be here studied. Actually, in practice, probably, neither case is often met with; the real condition of the journal is usually intermediate between one or the other pair of these type-examples.

It is evident, from what has been just stated, that the friction of journals, other things being equal, depends greatly for its amount upon the method of distribution of pressure, and is not necessarily, and probably may not be often, measured exactly by the product of the load on the journal by the coefficient of friction. It may be sometimes, and in fact often is, very much greater. It thus becomes an important problem to determine the manner in which variation of intensity of pressure affects the total resistance due to friction, and the method of that varia-

temperature, and on the value of the co- tion as produced by the different modes

of fitting journals.

THE WORK DONE AND HEAT DEVELOPED, by the friction of any journal, is measured by the product of the total normal pressure on its rubbing surfaces into the mean coefficient of friction, and into the space traversed by the surface of the journal, relatively to the surface of the bearing, in the given time,

If p represent the mean intensity of pressure, l the length of journal, θ the angle over which the pressure distributed, r_1 the radius of the journal, f the mean coefficient of friction,* and n the number of revolutions made in the given time, the work of friction will evidently be

$$U = p.l.r_1 \theta. f. 2 \pi r_1 n$$

= $2 \pi r_1^2 f p ln \theta$. . . (1)

When $\theta = \pi$, as in a journal receiving no pressure from its cap,

$$U = 2 \pi^2 r_1^2 f p l n;$$

and when $\theta = 2\pi$, as when the cap is screwed down hard,

$$U=4 \pi^2 r_1^2 f p l n$$
.

When the load is fixed, the intensity of pressure varies inversely as the area of the journal, and $p l r_1 \theta$, becomes constant. Hence in such cases, the resistance of friction, $f p l r \theta$, is constant, and the work of friction and energy wasted becomes proportional to the diameter of the journal; while both quantities are independent of the length, except so far as it affects the coefficient of friction. Journals are therefore properly proportioned by making their diameter such as is dictated by considerations of strength and safety against "springing," and determining their length by reference to the loss of work by friction and the liability to heating.

The minimum limit, as to length, is set by this last consideration. As has been fully shown by the writer, the coefficient of friction increases with increase of bearing area and consequent decrease in intensity of pressure; the conclusion therefore follows that bearings should be as short as is consistent with security against This conclusion is the more heating.

^{*} With good lubrication, it may be assumed that, in heavy machinery and under pressures not far from 100 pounds per square inch (7 kgs. per sq. cm.), the value of f may be reduced below one per cent.. varying approximately inversely as the square root of the intensity of pressure.

important from the fact that a long journal is liable to spring, and thus to concentrate pressure at the end, and to cause heating in that way. With every diameter of shaft, therefore, there is a limit beyond which no increase of length of journal will prevent heating. With a given shaft, heating under a given load, no increase of diameter will reduce liability to heat—if the shaft does not spring—and increasing its length may afford advantage only up to a limit.

The Heat Due to Friction, H, is proportional to the work done on the journal, and is measured in thermal units by the quotient of that work U, by the mechani-

cal equivalent of heat J, i. e.,

$$H = \frac{U}{J} \dots \dots (2)$$

This heat is carried away by conduction to adjacent masses, and by radiation. If it is carried away as rapidly as it is produced, the journal remains cool; if not thus carried off, the journal heats up until the rate of dispersion is equal to that of production, or until it becomes necessary either to apply cooling agents or to stop the machine.

THE TEMPERATURE ATTAINED by a journal when thus heating is limited by the facilities for conduction and radiation of heat from it. The maximum safe temperature is that beyond which liability to rapid and dangerous heating is incurred, and is always below the temperature of decomposition or vaporization of the lubricant. A warm journal will often work better than a cold one; a hot bearing is always a source of danger. A journal so proportioned as to run warm with good lubrication is to be watched with the utmost care. As already seen, since the tendency to heat increases directly as the intensity of pressure, and as the amount of work done, and inversely as the area across which the heat can be transmitted, the diameter of the journal, if it be sufficiently strong and stiff, does not affect this phenomenon.

Case 1.—The Perfectly Fitted Journal is the most interesting of the three cases here to be considered. When a journal is exactly fitted to its bearing,* as is usually the fact, without pressure,

the action of the load will cause a minute change of form, which, although quite imperceptible, will produce a variation of intensity of pressure between the rubbing surfaces, from a maximum on the portion normal to the line of direction of the resultant load, to zero on the surfaces parallel to that line, and according to a simple and easily determined law.

This Method of Distribution of Pressure, which was, as he believes, originally investigated by the writer, is determined in the following manner:

The maximum intensity of pressure under which any journal of good form and correct proportions may be worked, is from 500 pounds to the square inch, with iron journals, to about 1,000 pounds with steel (35 to 70 kgs. per sq. cm.); the elastic limit of the bearing metal is always far above these figures, and that of the metal of the journal usually very much The compression of the higher still. metal, under working pressure, will be proportional to the intensity of the pressure at each point, and this principle will determine the law of distribution of press-The intensity of the pressure will be everywhere proportional to the elastic displacement of the metal.

Let p represent the intensity of pressure on any element of the surface of the journal having a length l, and a breadth $r_1 d\theta$, and let N represent the normal pressure on this elementary area $lr_1 d\theta$; then

$$N = p \, l \, r, \, d\theta \quad . \quad . \quad . \quad (3)$$

The sum of all the vertical components of these elementary normal pressures, $p = N \cos \theta$, where θ is measured from the vertical, is equal to the load W on the journal; *i. e.*,

$$W = \int p \, l \, r_1 \cos \theta \, d\theta. \quad . \quad (4)$$

But the normal pressure p varies from a maximum, at the bottom of the bearing, to a minimum at the sides, there becoming zero when the bearing is a semi-cylinder. At intermediate points the normal pressure is

$$p = p_1 \cos \theta$$
,

in which quantity p_1 is a constant, the value of which is to be determined. The value of p being obtained, and introduced into the formula,

^{*}The custom now common of grinding journals to size, and sometimes of scraping the bearing, makes this an increasingly frequent case.

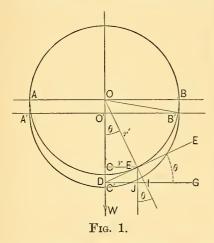
$$W = p_1 l r_1 \int \cos^2 \theta \ d\theta. \quad . \quad (5)$$

which is to be integrated between the limits

$$\theta = +\frac{\pi}{2}, \ \theta = -\frac{\pi}{2},$$

to obtain W in terms of p_1 , when the journal bears upon a semi-cylindrical surface, or between the positive and negative values of θ for any other method of bearing. From the relation thus obtained the value of p_1 is deduced. It will be seen that p_1 is the measure of the maximum intensity of pressure between the rubbing surfaces, occuring when $\theta = 0$, *i. e.*, at the bottom line of the bearing.

To Determine the Maximum Pressure p' on the journal, let A C B, Fig. 1, repre-



sent the trace of the bearing surface upon the vertical plane, the journal being perfectly fitted and unloaded. When the load comes upon it the journal will sink a minute distance, OO', CC', AA', BB', and will rest in equilibrium between the elastic resistance to compression, thus brought into play in the metal, and the weight sustained by the bearing, the surfaces of contact taking the new position A' C' B', of which every point now lies directly under its original position, and at a distance from it equal, at every point, to O O'. The compression of the metal in the direction of the normal pressure p, will be at each point, as E, equal to E I. The product of this vertical displacement, E J, into $\cos \theta$; and the intensity of the pressure, the elastic limit of the metal

not being exceeded, will be proportional to this compression, varying from 0 at B' to a maximum p' at C'. At any intermediate point, the compression is, for a small total depression of the shaft $\overline{OO'}$ cos. θ , and the intensity of the pressure, consequently, p' cos. θ .

Since the load, W, is sustained by the sum of the vertical component of these normal pressures, each of which is of the

intensity,

$$w = p \cos \theta = p_1 \cos^2 \theta,$$

$$W = \sum w = p_1 l r_1 \int_{-\theta'}^{+\theta'} \cos^2 \theta d\theta,$$

$$= p_1 l r_1 \left(\frac{1}{2} \theta' + \frac{1}{4} \sin 2 \theta\right)_{-\theta'}^{+\theta'}$$

as before, and

$$p_1 = \frac{\mathbf{W}}{lr_1} \div \left(\frac{1}{2} \theta + \frac{1}{4} \sin 2 \theta\right) + \frac{\theta'}{-\theta'} \quad . \quad . \quad (6)$$

When $\theta' = \frac{\pi}{2}$,

$$p_1 = \frac{W}{1.57 l r_1} = \frac{0.64 W}{l r_1};$$

and the pressure at any point, E, of the journal, has the intensity,

$$p = p_1 \cos \theta = \frac{0.64 \text{ W} \cos \theta}{l r_1} . \qquad (7)$$

When $\theta' = \frac{\pi}{3}$,

$$p_2 = \frac{W}{1.48 \ lr}$$
; $p = \frac{2}{3} \frac{W \cos \theta}{l r}$, nearly; (8)

and the maximum pressure is nearly equal to four-thirds the load on the journal divided by its projected area on the horizontal plane, and is very nearly the same as in the previous case, although one-third the bearing surface has been removed. This is often done by engineers in charge of heavy machinery, to prevent risk of "gripping" or "binding," should the bearing heat.

It is evident that the same method applies to the case of the spherical journal.

The Extent of Compression is determined by the magnitude of the modulus of elasticity of the metal compressed, thus, for a pressure of 1,000 pounds per square inch (70 kgs. per square cm.) on a bronze bearing, the maximum compression would be but $\frac{1}{12000}$ the thickness of the "brass."

The Force of Friction, at any element, E, is, for the full journal,

$$fp = \frac{0.64 \text{ W}\cos \theta}{lr}, \quad . \quad . \quad . \quad (9)$$

and varies from zero at $\theta = 90^{\circ}$ to a maximum, at $\theta = 0$, when

$$fp_1 = \frac{0.64 \,\text{W}}{l \, r_1}$$

The Total Pressure on the bearing is

 $f P' = 1.27 f W \dots \dots$ (11)The Moment of Friction is

$$M = f P' r_1 = 1.27 f W r_1$$
 . . (12)
The Work of Friction is

$$U=M \ a=1.27 \ f \ W \ a \ t \ r,$$

=2.5 \ f \ n \ r, \ t \ \pi \ W, \ \ . \ . \ (13)

where a is the angular velocity of the shaft, t the time taken, and n the revolutions made in the unit of time.

The Power lost in Friction is

$$U \div 550 t = 2.5 f n r_1 \pi W \div 550, (14)$$

when the units are British and the time is measured in seconds.

As will be seen later, the resistance, the work done, and the power wasted, are 1.3 times as great as in a journal loosely fitted, in which the rubbing surfaces are in contact only along a narrow band parallel to the axis of the journal. The case above considered assumes a fit originally and no subsequent wear. In such case, the journal must be of such size that the maximum pressure, p_1 , may be below that at which the unguent is liable to be forced out, or heating to occur.

Case 2.—Uniform Pressure on the Rubbing Surfaces may be observed in cases of journals so small as to wear slowly under their loads, or, perhaps, when heating, as is often the case, causes the "brass" to grasp the journal by familiar cases to every mechanical engi- attained is

neer who has had much experience, especially if accustomed to the management of steam machinery.

In well-designed machinery, a bearing is usually composed of a softer metal than the journal which it supports; it therefore takes the wear, and if the extent of rubbing surface is small the journal is merely "smoothed up," while the bearing wears down. If the surface is too small, the bearing may be abraded and "cut," and both it and the journal rapidly injured. If, however, the surface under pressure does not cut, wear takes place slowly, and without excessive waste by friction. Every bearing surface, if not abraded, will, whether fitted or not, wear under heavy pressure, but with decreasing rapidity, until all parts sustain a certain intensity of pressure, when the rate of wear becomes a minimum, under a pressure which is a minimum for that bearing under the existing conditions as to lubrication. In some cases, the whole bearing surface may not be brought into play, the uniform pressure, so established by wear over a part of it, being sufficient to carry the load without further wear. These two cases are probably the most usual in all cases of heavily loaded, or carelessly fitted, journals, as the preceding case represents the usual case of wellfitted, lightly, or fairly loaded bearings. in every case, there is a certain pressurelimit, above which wearing will take place and below which it becomes inappreciable; the bearing will therefore wear down until the pressure due the load is so distributed that this pressure-limit is everywhere reached over a certain limited area, and wear ceases, or until all parts of the bearing are brought to a state of minimum wear under a uniformly distributed press-

In the case here studied, the pressure is of uniform intensity, p_1 ; that on any elementary strip of bearing, of length l and breadth $r_i d\theta$, is $p_i l r_i d\theta$; its vertical component is $p, lr, \cos \theta d\theta$, and the total load is, for a semi-cylindrical journal,

$$W = p_1 l r_1 \int_{\theta}^{\theta} \frac{\theta = +\frac{\pi}{2}}{\theta} \cos \theta d\theta$$
$$= 2 p_1 l r_1; \quad . \quad . \quad . \quad (15)$$

springing the sides inward. Both are and the intensity of the uniform pressure

$$p_1 = \frac{W}{2 l r_1} \dots (16)$$

The Total Pressure on the journal surface is

$$P' = p_1 l \pi r_1$$

= $\frac{1}{2} \pi W = 1.57 W$. . . (17)

or 0.57 greater than the load.

The Total Force of Friction is

$$f P = 1.57 f W$$
 . . . (18)

The Moment of Friction is

$$M = f P' r_1 = 1.57 f r_1 W$$
 . (19)

The Work of Friction is

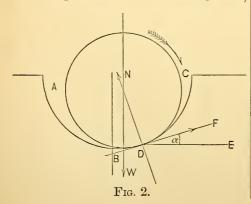
$$\begin{aligned} \mathbf{U} &= \mathbf{M} \ a = 1.57 \ a \ f \ t \ r_{_{1}} \mathbf{W} \\ &= \pi_{_{2}} f \ n \ t \ r_{_{1}} \mathbf{W}, \\ &= 10 \ f \ n \ t \ r_{_{1}} \mathbf{W}, \text{ nearly.} \end{aligned}$$
 (20)

or 1.57 that on a flat surface, or on a

loosely fitting journal.

Were the angle of contact reduced, making the angle $\theta' = 30^{\circ}$, the friction becomes but 5 per cent. greater than that of an equally loaded flat surface, or of a loose journal. It is thus seen that, where ample area of bearing surface can be secured, it is best given the form of a strip or band lying along the bottom of a long "brass," rather than made to cover the full semi-circumference of a shorter journal.

Case 3.—A Loosely Fitting Journal, A B C, before wear has produced a sensible widening of the line along which contact originally takes place between journal and bearing, when in operation, carries its load at a line parallel to the axis of the journal, and at one side of the line of vertical resultant pressure (Fig. 2). If at the lowest point, B, at the starting, it rolls up the side of the bearing until



at some point, D, the inclination becomes equal to the angle of friction B N D, E D F, when it ceases its upward movement and continually rotates, sliding on the line whose trace is D, as long as the coefficient of friction remains constant, or rising with increasing, and falling with decreasing, friction, continually finding new positions of equilibrium until motion ceases, or the conditions again become constant.

At any one instant, there are three forces in equilibrium, the weight W, on the journal, the normal reaction, N, of the bearing, and the resisting force of friction, F = f'N, which may be represented by the sides of the triangle N B D. Then, since N and F are at right angles

$$W^2 = N^2 + F^2$$

= $(1 + f^2) N^2$ (21)

The Normal Pressure is

$$N = \frac{W}{\sqrt{1+f^2}}$$
 . . . (22)

The Force of Friction is, since $a = \varphi$, the angle of friction,

$$F = \frac{f'W}{\sqrt{1+f^2}} = \frac{W \tan \theta}{\sqrt{1+\tan^2 \phi}} = W \sin \phi (23)$$

$$= f'W \text{ nearly.}$$

The Moment of Friction is

$$\mathbf{M} = \mathbf{F} \ r_1$$

$$= \mathbf{W} \ r_1 \sin \varphi$$

$$= \frac{f \ \mathbf{W} \ r_1}{\sqrt{2 + f^2}} \quad . \quad . \quad . \quad (24)$$

The Work of Friction, or energy wasted, is

$$U = W a t r_1 \sin \varphi = \frac{f W a t r_1}{\sqrt{1 + f^2}}$$
$$= 2 W \pi n t r_1 \sin \varphi = \frac{2 W f n t r_1}{\sqrt{1 + f^2}}. \quad (25)$$

This case is thus seen to be that producing least waste of work and energy, and hence, in that respect, most desirable; but it is evidently a purely ideal case which can never be obtained in practice. If approached too closely, rapid wear, heating, and all the consequent cost and damages are increased. Case 3d is that of minimum friction, but of maximum wear and heating, as Case 1st that of minimum wear, and Case 2d that of maximum friction. In practice, the best ar-

rangement is usually, so far as the writer due to grasping or binding action decan judge from his own experience, that creases efficiency. of freeing the sides of the bearing by 30° from the horizontal, and even 60° for very long, stiff journals, moderately loaded. This gives a modification of either Case I. or Case II., and, on the whole, minimum friction and wear.

In conclusion, it may be considered

proven that:

spherical bearing of ample area of rub- unit of area of bearing surface is apbing surface, will, in the absence of wear, proximately the same, whatever the dihave the pressure distributed in such ameter of journal, within moderate limits; manner as to make it zero at the sides, and a maximum at the bottom of the friction may be considered as constant. bearing, varying at intermediate points as the cosine of the angle included be- determined by the strength and stiffness tween the given point and the bottom of demanded, and not by the liability to the journal.

(2.) The friction on such a cylindrical journal, and the lost work, exceed by above one-fourth that of the ideal case of bearing on a line, or that of flat sur-

faces under the same load.

(3.) A bearing so proportioned as to wear constantly, but without "cutting," will be subjected to uniform pressure throughout the area of rubbing contact.

(4.) The friction on such a bearing is nearly 60 per cent. in excess over that of the ideal case, or on a flat surface similarly loaded; it should always be relieved by freeing the sides from pressure in the manner often practiced by engineers, as above described.

(5.) Any journal, wearing smoothly and symmetrically, and without shake, will in time wear to a fit, such that the pressure upon its surface will be of uniform intensity throughout the whole area brought into bearing, and the rate of wear reduced to a minimum, while the waste by friction becomes a maximum.

(6.) Maximum efficiency of machinery in which journal friction is the main source of waste of work and energy, is secured by giving the journals such diameter that they will neither twist nor spring under their loads, such length that the load may be carried principally on the lower portion of the bearing, and such form that the "brass" shall not bind or grasp the journal, or in any way subject the journal to serious in which expression d is known already lateral pressures. All lateral pressure by calculations of strength.

The proper size of journal is, as is evicutting them away so as to clear the dent from what has preceded, deter-journal entirely to an angle of at least mined only in part by the consideration of the amount of power and energy lost by its friction. Since to increase or diminish the diameter of a journal increases the speed of rubbing in precisely the same proportion in which it diminishes the intensity of pressure produced by any given load it is evident that the work (1.) A perfectly-fitted cylindrical or wasted and the heat produced on the for, within such limits the coefficient of The diameter of journal is, therefore, heat, and is calculated by the rules for strength of materials.

> The length of a journal is determined by reference to the laws of friction. A convenient method is to fix, by reference to experiment, a quantity of work of friction which may be safely allowed for the proposed journal, reckoned per unit of its area. Thus, the writer has found for the crank pins of marine engines, under intermittent pressure, 60,000f, measured in foot-pounds, to be a good allowance; Rankine found 44,800f to be a good figure for locomotive practice; 50,000f is an intermediate figure sometimes taken for general practice. For unintermitted pressure, still smaller values

must be taken.

Then the work of friction is nearly per unit of area,

$$\frac{f \, P \, V}{l \, d} = 60,000 \, f, \quad . \quad . \quad (26)$$

and

$$\frac{P}{l \ d} = p = \frac{60,000}{V} \dots (27)$$

Thus the intensity of pressure is limited by the velocity of rubbing, and the given load, P, on the proposed journal being divided by this pressure, p, the length must be at least

$$l = \frac{P}{p d} \dots \dots (28)$$

ON WATER SUPPLY.

Papers read before the Conference of the Society of Arts on the Water Supply held at the International Health Exhibition in July.

From the "Journal of the Society of Arts."

Sources of Water-Supply. BY JAMES MANSARGH,

M. Inst. C. E., and M. E., F. G. S., F. M. S.

It used to be a popular belief that if a well were sunk at any place to a sufficient depth into the ground, there would be reached an inexhaustible reservoir of water, a store that had been filled in some mysterious manner at the creation of the world, and would suffice for the use of man for all time.

It is now well known that all supplies of water, whether found upon the surface or below it, in underground depths, are derived from the rain which falls upon the earth, and that it depends upon the geological character of the surface receiving the rain whether it shall run off in the form of streams and rivers, or soak in and be apparently lost.

Rain is produced from the evaporation of invisible aqueous vapor, principally from the ocean, by means of solar heat, its condensation, primarily into the shape of clouds, and subsequently into the form of drops, which fall to the ground.

The sea is thus a storage reservoir of boundless capacity, and the sun is the great prime mover which pumps the water up from this reservoir, distributes it over the land, and lifts it to the hills, where it may be impounded in natural or artificial lakes, and thence delivered by gravitation to the claims below.

After being discharged on the earth in the shape of rain or snow, a part of the supply of Manchester. water is re-evaporated, but the greater part begins at once to travel downwards, either over the surface, in the form of rills and streams, and so on to the ocean, whence it came, or through the surface, if this is permeable, into fissured or porous rocks below.

A portion of this latter water passing into the ground at high levels, has several courses open to it. It may appear in the shape of springs at lower levels, or rise in the beds of rivers, or run out

through fissures on to the sea beach, or sink below sea level, whence it will be recoverable only by artificial means.

Nature has in this way provided water from one great source in ample quantity for the use of man, but works of varying character, under differing local circumstances, must be constructed to store and utilize it.

Altitude and the geological structure of a district are the two principal factors which determine what the source of water supply must be in such a district. The two great classes into which sources may be divided are (a) above-ground and (b) under-ground sources.

The former (a) has several subdivisions, which may be described as fol-

1. Water may be taken from the heads of streams by laying pipes right up to the springs, to convey it away for supply without any intermediate storage, as in the case of Lancaster. This is a source which in some sense belongs to the two classes, for the water is taken just as it ceases to be underground water, and is being delivered on to the surface above ground.

2. It may be obtained from a natural lake like Loch Katrine, as in the case of

Glasgow.

3. It may be collected from a highlying watershed area, by impounding a number of small streams in artificially constructed reservoirs, as is done for the

4. It may be taken from a large river flowing past the town, and is done in the case of the Thames and Lea for the sup-

ply of London.

The second class (b) is not divisible in the same way as (a), but may be taken as embracing supplies of water obtained from many varieties of geological stratification, such as chalk, oolites, coal measures, millstone grit, magnesian limestone, Bagshot sands, and many others.

All water, when discharged upon the

earth as snow or rain, is practically pure, but its character is very soon changed by the material it comes in contact with on the surface, or in passing through underground fissures and channels. Take, for example, the rain which falls upon the chalk downs of Sussex, or any other similar geological area. It sinks at once beneath the smooth and rounded surface, and percolates through innumerable minute cracks or larger fissures, dissolving away the chalk which it touches, and finally issues naturally in springs along the coast, or is pumped out artificially, a water which contains from fifteen to twenty-five grains per gallon of carbonate of lime.

Such an alteration in character depends, of course, upon the nature of the rocks which the water traverses, some rocks being easily soluble, others not.

The taking up of lime or magnesia in this way has the effect of rendering the water "hard," that is, increasing its soapfacturing processes this is a most undecountry are located in districts where soft water is easily procurable.

which yield, as a rule, soft water: Igneous, metamorphic, Cambrian, silurian (non-calcareous), Devonian (non-calcareous), millstone grit, coal measures (noncalcareous), lower greensand, London and Oxford clay, Bagshot sands, non-cal-

careous gravels.

ites, upper greensand, chalk.

comparatively soft, but this quality is coffee. fully secured by the character of the As works, which consist of large reservoirs bottle or tumbler, the tinge is rarely impounding the water which has princideeper than a very faint straw color. pally run merely over the surface. For There is nothing harmful in this coloring dietetic purposes, the quality of hardness, matter, because it is of purely vegetable if not excessive, that is if it does not ex- origin, and to some extent it may be receed twelve grains on Dr. Clark's scale moved by storage in open reservoirs,

(equivalent to twelve grains of bi-carbonate of lime per gallon) is not considered objectionable on physiological grounds. For ordinary domestic purposes and especially for personal washing and cleaning generally, soft water is infinitely preferable to hard, both in respect of comfort, efficiency, and economy.

Taking into account all the purposes for which water is used, it can hardly be questioned that a pure soft-water supply is, on the whole, preferable to a pure hard-water supply. The term "pure" is here used to imply the absence from the water of organic impurities as distinguished from the dissolved inorganic matters which have before been referred to. Except at producing hardness, the inorganic matters usually found in water are practically harmless; but organic pollutions may be of the most disgusting and dangerous character, those, for instance, which are the result of contamination with town sewage or of cesspool manure.

It is to avoid the risk of such polludestroying properties. For many manu-tion that many towns have in great measure been led to seek their sources of supsirable quality, and we therefore find that ply on elevated moorlands, above the many of the important industries of the level at which arable cultivation is carried on, and where it follows that there are no towns or villages, and the scattered pop-The following are the formations ulation is very sparse. In this country the plough is rarely seen above the 800feet contour, and, as it will not pay to cart manure to such an elevation, these high lands are merely used for the pasturage of sheep and the rearing of grouse.

Water obtained from such sources is On the other hand the following geo-practically, therefore, in the condition in logical formations almost invariably yield which it falls from the clouds as snow or hard water: Silurian (calcareous), Devo-rain. The only impurity it may contain nian (calcareous), mountain limestone, is a little organic matter derived from coal measures (calcareous), new red sand- passing over the peaty soil, which often stone, conglomerate sandstone, lias, ool- occurs on high moorlands, especially where the summits are broad and com-The manufacturing towns of Yorkshire paratively flat. This contact with peat and Lancashire obtain their supplies and with growing heather gives a stain from sources which, even if the water to the water to such an extent that, when had passed underground, would leave it seen in deep reservoirs, it is like dark

As seen in an ordinary white glass

count of the enormous expense that water again fit for human consumption. would be entailed in the construction of past thickly populated towns and vil-disease induced in the way suggested. lages, contain water which has necessamatters which the water contains are con- any mischief. verted by the agency of oxygen into again becomes fit for the use of man.

This statement must, however, not be made without some reservation and explanation, because chemists of the very highest standing are not agreed as to the Lancaster, whose works supply a popuextent to which rehabilitation of the lation of between 30,000 and 40,000. water is carried. This has, in fact, become quite a burning question, and the battle has been fought long and frequently over the water which is taken from the Thames, and delivered for consumption

by the inhabitants of London.

The difference of opinion is now narrowed down into a small compass, and to outsiders it would appear that there is a or ten miles from the town, in a southchance, sooner or later, an agreement may be come to between the authorities.

As representatives of the two sides may be named Dr. Frankland and Dr. Meymott Tidy. that oxidation is effective in burning up, or converting into a harmless condition, fells which is secured by Act of Parliaeven such foul contaminations as human sewage, if this is in a normal or healthy condition; but he contends that the virulent zymotic diseases are propagated by feet above the sea. organized germs contained in the sewage which are indestructible, and which may travel scores of miles in a running stream without being deprived of their pasturage, and heather. Interstratified fatal potency.

or running in open channels exposed to that there is no evidence of the existence of these animated germs, and affirms that Many towns are so located in this a run of a few miles in a river fully oxycountry that it is practically impossible genated, and in which the pure water that they should obtain pure water sup- bears a sufficiently high ratio to the polplies from elevated watersheds, on ac-luting matter, will suffice to render such

Dr. Frankland's theory is naturally a the necessary works. Such places must disquieting one, and his opponents cerbe content to be supplied from rivers in tainly have facts in their favor, for Lontheir immediate neighborhoods, and don is undoubtedly one of the healthiest which, having run their courses through cities in the world, and its inhabitants many miles of highly manured lands and have never been known to suffer from

The "germ" theory is, however, makrily become polluted by the washings ing steady advances under the investigafrom the lands and the sewage from the tions and researches of competent men, towns. Such sources as these would be and it is to be hoped and expected that inadmissible, but for the great rehabili-lif the historic germ is at last discovered, tating process which nature silently car- and exhibited to the incredulous gaze of ries on in a river, and to which chemists Dr. Meymott Tidy, he, or some of his conapply the term "oxidation." In this freres, may speedily discover a method wonderful process the polluting organic of scotching it before it has time to do

It may now be convenient to describe harmless inorganic salts, and the water shortly a few typical examples of the utilization of the different sources of supply which have been thus generally referred

I. Take first, such a case as that of The town is situated on the River Lune, about seven miles above its junction with Morecambe Bay, and is built upon a site which, rising from the river, varies in elevation from 15 to 200 feet above Ordnance datum, or mean tide level. The water is obtained from the high moorlands of Wyresdale, at a distance of eight easterly direction. These fells, as they are locally called, constitute the extreme north-easterly portion of the watershed of the River Wyre, a small river which Dr. Frankland admits also falls into Morecambe Bay near the town of Fleetwood. That portion of the ment as a source of water supply for Lancaster, has an area of 2,700 acres, and an altitude varying from 850 to 1,800

The geological formation of the gathering ground is millstone grit, covered with scant herbage suitable for sheep with the beds of permeable grit stone Dr. Tidy contends, on the other hand, there are layers of impervious shale and leading their combined waters to

One of these mains forms part of the dry weather flow increased in volume. original works constructed under the son, C. E., C. B., in the year 1852; the other, which runs (broadly speaking) parallel to the first, but about 200 feet lower down the hill side, was laid six out by the writer.

The water derived from these is of necessity of the purest possible character, for the rain which feeds the springs falls upon the clean open moorland, and sinks at once into the millstone grit rock, in which it finds nothing to dissolve and cause hardness, and nothing to organically pollute.

The water issues from the springs in a bright sparkling condition, at a constant temperature of about 45° F.; it contains only one grain in 15,500 of solid matter, and its hardness is under 1° on

Clark's scale.

This may be fairly regarded as an ideally perfect source of supply, and it has been an inestimable boon to the inhabitants, especially as it replaced water obtained from shallow wells in the town, polluted in the vilest possible manner by percolation from numberless foul and reeking privy pits and middens.

Between the fells and the service reservoir, which is situated on the town moor 240 feet above Ordnance datum, the country is intersected by several valleys, across which the water is con-

veyed in iron pipes.

At two intermediate points the pressure is broken by a small covered tank, and the water is never exposed to the open air from the time it sinks into the ground as rain or snow, and is drawn from the consumer's taps in the town.

Perhaps it may be as well to explain here that, when water is obtained from elevated watershed areas of this character, Parliament almost invariably insists upon for such abstraction. This compensation Drunkie 20 feet, the raising in both cases

which, at various levels, throw out the is secured by the construction of reserwater percolating downwards from the voirs somewhere upon the main river or surface, in the shape of springs, and a its tributaries, in which water is stored number of these springs have been in- in time of flood, and given out in a contercepted by small pipes communicating stant stream in times of dry weather, with mains laid along the hill side, the assumption being that floods are utterly useless, if not damaging, to riparian the south-west corner of the reserved owners and mill owners, whilst it is of advantage to every interest to have the

Thus, in the Lancaster case, whilst the superintendence of Sir Robert Rawlin- Corporation have the right to take 2,000,-000 gallons a day from the springs for the use of the town, they were put under the obligation to construct upon the River Wyre a reservoir capable of holdyears ago, as part of an extension carried ing 185,000,000 of gallons, from which the millowners have the right to draw water according to their needs during the summer months. By means of such works, all the parties concerned are very greatly benefited.

> II. The second type of utilization of sources which may be referred to, is that which is exemplified on so magnificent a scale in the works supplying Glasgow, and constructed from the designs and under the superintendence of Mr. John

Fredrick Bateman, C. E.

In this case, advantage is taken of three natural lakes, viz., Loch Katrine, Loch Venachar and Loch Drunkie. watershed area draining into these lakes is 45,800 acres in extent, and consists of unpolluted sparsely populated moorlands, the geological formation being of

the silurian age.

Loch Katrine has a water surface of 3,000 acres, Loch Venachar 900 acres, and Loch Drunkie 150 acres. They are all of course supplied by the rain which falls upon the 45,800 acres, and as a considerable proportion of this area is of a peaty character, the streams which run down the mountain sides are frequently as dark as London Porter. By the deposit of the heavier parts of the peaty matter, and the bleaching action of the air, the water is drawn from Loch Katrine with only a faint tinge of color.

The two smaller lakes are utilized as compensation reservoirs, the artificial storage necessary being obtained by raising the original normal level of Loch Venachar 5 feet 8 inches with power to "compensation" being made to the river draw it down 6 feet, and by raising Loch being done by masonry dams across the outlet valleys, furnished with draw-off sluices.

The storage for the supply of Glasgow is obtained by works which raised the normal level of Loch Katrine 4 feet and admit of drawing down 3 feet. capacity is, therefore, 3,000 acres of area, by 7 feet in depth, equivalent to nearly 1,000 million cubic feet, and competent to furnish 50 million gallons a day during

a four months' drought.

The water surface in Loch Katrine is 360 feet above mean tide level at Glas-The conduit conveying the water to the city commences on the south side of the lake, about three miles from its western extremity, and runs generally in a southerly or south-westerly direction. At 26 miles from the Loch it discharges into an artificial reservoir of 70 acres in extent, and holding 500 million gallons near Mugdock Castle, the top water of this reservoir being 311 feet above mean tide at Glasgow. Two lines of three feet cast-iron pipes, one seven miles long and the other eight miles, convey the water to the city.

For thirteen miles out of the 26, between Loch Katrine and Mugdock, the conduit is formed by tunneling through very hard rock, such as whinstone, gneiss, and mica slate; the tunnels being seventy in number, nine miles of the remaining length is "cut and cover" work, and the rest consists of cast-iron or wrought-iron

pipes across valleys.

The advantage of such a source of supply as Glasgow's is the facility and small cost with which the storage capacity necessary to furnish the requisite daily quantity for consumption and compensation

is obtained.

In Loch Katrine, the narrow outlet from the lake had only to be dammed up four feet, requiring artifical works of the simplest character, entailing no risk or contingency in their execution. Having a flat area 3,000 acres in extent to begin with, a simple plank one foot high would have sufficed to impound 816,000,000 gallons. The desirability of securing such a reservoir site as this can only be fully appreciated by those who have had the responsibility and anxiety of forming large storage reservoirs, by the construc-

in such reservoirs, and in cases like Loch Katrine, will be better realized in considering the next type.

III. The third type of works for the utilization of mountain watershed sources of supply is well exemplified in the Longdendale valley, where a number of reservoirs have, during the last thirty years, been constructed for the supply of Manchester. Here, instead of having a level plain 3,000 acres in extent as in Loch Katrine, upon which to commence as the bottom of a reservoir, was a valley with a fall along the bed of its main stream—the Etherow—of between 60 ft. and 70 ft. in a mile. Across this valley five embankments have been constructed of earthwork, one above another, forming five lakes with a combined water surface area of 462 acres. Beginning from the lowest part of the valley, the following is a list of the reservoirs, viz:

_					
E	leight	7	Vater		
of	Bank				Capacity.
	Feet.	A	cres.		Gallons.
Bottoms	66		50		407,000,000
Vale House	55		63		
Rhodes Wood	75		54		
Torside		٠.	160		1,474,000,000
Woodhead	80		135	٠.	1,181,000,000
m . 1			400		2 227 222 222
Total	376		463		3,905,000,000

These embankments, which cost something like £100,000 apiece, have an aggregate height if placed one above another of 376 feet, and the quantity of water they impound is 3,905 million gal-The raising of the water surface of Loch Katrine 5 feet would create the The watersame amount of storage. shed area supplying these reservoirs is 9,300 acres, and the geological formation is millstone grit. The gathering ground is a portion of the western slope of the "backbone" of England, otherwise the Pennine range, upon which, over its whole length on both sides, many similar works are located for the supply of the manufacturing towns of Lancashire and Yorkshire. The rocks in this district are very much fissured and broken, and the rain falling upon the higher grounds percolates below the surface and re-appears as springs at lower levels. Advantage is taken of this by conducting tion of high embankments across valleys. the spring water along special channels The relative amounts of labor and outlay into the Rhodes Wood reservoir, from the town.

Although the quantity of water yielded by the whole ground is that due solely to its area and the rainfall upon it, the In this case the water will have to be fact of there being these springs renders it more valuable, because it implies that water which would have run off a district composed of harder and less pervious rocks, is here absorbed into the mass which thus acts as so much storage or reservoir space. The effect of this is to increase the dry weather flow of the streams, and to furnish water which is clear, cool and colorless. The average annual rainfall upon the 19,300 acres is about 50 inches, and the works utilizing this area are competent to provide 38,-000,000 of gallons per day, of which 13,-500,000 have to be delivered into the stream below the reservoirs as compensa-Besides the five reservoirs above named, there are other large impounding and service reservoirs at Godley, Denton, Gorton and Prestwich. the construction of these works enormous difficulties have been encountered, and at Woodhead, the highest reservoir of the series, the embankment, as at first made, was not watertight, so that a second trench had to be put down in which to build the puddled wall, and so much were the measures disturbed and distorted, that on the south side of the valley this trench had to be excavated to 167 feet below the surface of the ground, before sound and tight material was reached upon which the wall could be based.

may fairly be said to exhaust the methods water taken from the river below Tedof obtaining water from sources situated on elevated mountain gathering grounds. They are good examples of the gravitation system of supply, by which water is delivered at high pressure above the highest parts of the towns without any artificial pumping being required, the sun having done this work in the process

of evaporation.

IV. We will now consider a case where the town to be supplied is at such a distance from high ground that the cost, distances apart. Thus the Southwark of bringing it through conduits or pipes and Vauxhall Company have at Batterby gravitation is prohibitive.

which the supply is taken by a conduit to cultural district, and is thus not polluted by manufacturing refuse, and not seriously by either manure or sewage, it may be adopted as the source of supply. lifted by artificial means to such an elevation as is necessary to command the whole town.

> The water will also require filtration, because in running its course through the country the river receives the washing from the land, and in times of heavy rain, at all events, the water will be discolored and turbid through the presence of suspended matters.

The works for the supply of London are, in great part, of this character, the rivers Thames and Lea being the two

sources.

Three hundred years ago water was obtained from the Thames at London bridge, and pumped by means of a waterwheel under one of the arches through wooden pipes into the streets and houses in the neighborhood. These works were continued in operation for 200 years, and were supplemented early in the 17th century by other pumping stations, taking water from the Thames at Charing Cross, Battersea, Vauxhall, and Hammersmith, all within the range of tidal influence.

In 1848 the Lambeth Water Company obtained powers to go into the non-tidal portion of the river above Teddington Lock, and by the year 1851 they were in a position to deliver water by means of a large steam-pumping establishment

erected at Seething Wells.

In 1852 an Act was passed which made The three types of works thus described it unlawful for any company to supply dington Lock, or from any of the tributaries within the tidal range. This led, finally, to all the companies drawing water from the Thames, so re-arranging their works as to have their intakes above Moulsey Lock, in order to be above the junction of the River Mole, which frequently brings down very dirty water.

Owing to the changes in the points of intake, the works of the London companies are divided into portions at great sea the reservoirs, filter beds, and pump-Take a town built along the banks of a ing machinery constructed for the purpose river anywhere above the range of the of taking in water from the river at that tide. If this river flows through an agri- point. They are well known to all Lon-

which form a prominent object in the view from the trains running out of Victoria station.

These works are of so costly and extensive a character, that they could not be abandoned when the source of supply was changed to Hampton, 21 miles higher up the river, but the water abstracted there is pumped down to them through large cast-iron mains, to be filtered and distributed by the original machinery and

In the case of the Lambeth Company, the water is taken from the Thames at Molesey, and sent down to Surbiton, which is the site of the filtering and pumping station, through a large brick

conduit by gravitation.

tion of such a source as the Thames finest at the top. above London.

a state of great turbidity or muddiness. als above-mentioned, and has a total This is met by the provision of large reservoirs, which are always kept full so long as the water is coming down in effective portion of the filter is the sand, good condition, and the inlets into the river are closed, and they themselves are tion of diminishing the depth of filtering drawn upon when the water of the river is turbid.

capacity than at present, and were worked neer exhibits a filter composed solely of as subsidence tanks, that is to say, the 2 ft of sand resting upon 6 in. of gravel, water (which might be somewhat turbid) the total depth being only 2 ft. 6 in. In was let in at one end and drawn off only working the filters, the water is brought from the surface at the other, the sus- from the storage or subsiding reservoir pended matters causing the turbidity on to the top of the sand, and stands from subsiding to the bottom during the 2 to 3 ft. above its surface. It then perwater's slow passage through the tanks. colates downwards through the filtering

several companies have come under the away to be pumped for distribution. official supervision of Sir Francis Bolspent in increasing the efficiency of these worked, that is, the difference in level subsiding tanks by greatly augmenting betwixt top water and the draw-off. their capacity, and practically changing some cases this is only 2 or 3 inches. their character into that of storage res- The speed at which the water should pass ervoirs.

doners by reason of the tall stand-pipes them by gravitation; in others they are elevated above the ground, and the water is pumped into them. In either case it is next delivered on to the filterbeds, the construction of which is shown very clearly in the most interesting pavilion erected in the Health Exhibition by the water companies. These filters consist of reservoirs or tanks made either by excavation in the ground or partial excavation, and partial embanking, as circumstances may dictate, having their sides sloped and pitched, or of vertical brick, stone, or concrete walls. The bottom is formed in many different ways, but it is always furnished with a number of openjointed or perforated pipes or drains into which the water can pass, and by which it may be conveyed away to a pure wa-From these circumstances none of the ter chamber or pump-well. Upon this London works are good examples of the floor the filtering material is placed, and type now under consideration; but the consists of clean stones, flints, gravel, following description will explain the na-shells, and sand, arranged with the largture of the works required for the utilizatest sized material at the bottom and the

Probably the oldest style of filter shown First of all, then, provisions must be in the Exhibition is that designed by the made to meet the difficulty of the water late James Simpson, C.E., for the Chelsea arriving at the intake in times of flood in Company, and it contains all the materi-

depth of 6 ft. 3 in.

As, however, the really operative and modern practice is tending in the direcmaterial, and of omitting entirely several For inof the strata originally used. These reservoirs used to be of smaller stance, the New River Company's engi-In London, since the works of the material into the drains below, and is run

The speed of filtration may be adjusted ton, very large sums of money have been by the head under which the filter is vertically downwards through the sand In some of the works, these reser- used to be stated as 6 in per hour, which voirs are constructed at such a level gave 675 gallons per square yard per day that the water from the river flows into of 24 hours, but the London companies are now not filtering more than 450 to having the southern edge of its outcrop

filters consists principally of finely dividits southern outcrop extending from ed mineral matter washed from the sur- Croydon to Merstham. On the west the trace of animal matter. These impurities the north-east to near the coast of Norare caught almost entirely in the top folk and Suffolk. Portions of this vast half-inch of the sand, which in course of area are no doubt covered by impermetime they choke and render impervious. able drifts of varying character, but there The filter is then put out of use; the is still a very large tract of country upon water is drawn off, and a skimming of the which the rain which falls sinks below fouled sand is carefully removed and the surface, and goes to charge the great washed in apparatus which separates the underground chalk reservoir below. light muddy matter and leaves the clean loss of sand, and periodically additions have to be made of new material. After

bered—(1) being springs at high elevathis under ordinary conditions. tion, without storage; (2) being surface similar watersheds, impounded in artificial reservoirs; (4) being river waters filtered, and artificially pumped for sup-

There are in this country a few ex- impervious tertiaries. amples of hybrid schemes, that is, where water from comparatively low agricultu- where the chalk itself comes to the surral land is impounded in large reservoirs, face, but after heavy and continuous rains, and where it has to be subsequently fil-streams do appear and flow for a time, tered and pumped for distribution in the and these are known as "bournes." As water collected at a sufficient elevation to large quantity of water is, however, left supply a town by gravitation has to be in it below the level of any of these natu-

filtered before delivery.

sources of supply, and one or two ex- overlying impervious beds of London amples will suffice to explain how these clay, and allowing the water to rise, as in are made available. We need not go far an artesian well. from home to learn all about one of the most important of these underground the London basin, and one of the metrosources, for it lies under our feet in the politan water companies, the Kent, obchalk forming one great feature of the tains its supply exclusively from such London basin.

500 gallons, or from 4 to $4\frac{1}{2}$ in. per hour. on the north of London about Hatfield. The matter which is arrested by the and the northern edge near Royston, and face of the land, of some vegetable and a chalk reaches as far as Devizes, and on

Possibly, the term "reservoir," though sand which is again put upon the filter. Of a common one, is a little misleading as course, the washing process involves some applied to the chalk, because for water supply purposes, a large proportion of After that which percolates into its mass is not filtration, the water is in a fit condition recoverable by ordinary means. It is the to be pumped and distributed to the con- water which circulates through the cracks and fissures which is really available, and Thus far we have been dealing with not that which is held in the minute ca-"above ground" sources of supply, ob- pillaries of the mass. Some chalk will tained either by gravitation or by artificontain 20 per cent. of its own bulk of cial pumping, under the four heads num- water, and yet will not yield a drop of

Of the water which thus sinks into the water from moorlands drawn from natu-chalk, a large portion finds its way out ral lakes; (3) being surface water from again into the bed of the river, another portion appears in the shape of large springs, such as those at Carshalton and Croydon, which go to form the River Wandle, by flowing over the edge of the

Very rarely are there any streams There may also be cases where the chalk is 500 or 600 feet thick, a very ral outlets, and this water can be obtained We now come to the underground in London by sinking wells through the

There are a large number of wells in wells. The ordinary practice is to sink a London is actually built upon the ter- well from five feet in diameter upwards, tiary deposits, which consist of Bagshot and line the same either with brickwork sands, London clay, and the sands and or cast-iron cylinders down to the chalk. mottled clays of the lower strata; but This will pass through superficial gravels, underlying all these is a mass of chalk blue clay, bands of sand, mottled clay, &c., and sometimes on the top of the headings parallel to the coast, at about chalk a band of flints will be found. Below the bottom of the well a boring is inches in diameter, and lined with iron whilst in soft or much broken chalk, and left unlined where the material is more

compact.

In those parts of London which are not elevated many feet above the level of the river, the water rises to very near the surface of the ground, and in some cases overflows; but wherever large quantities are required, resort must be had to artificial pumping so as to lower the level of the water in the well, and thus open out a larger cone of exhaustion in the chalk. Favorably situated chalk-wells yield as much as 2,000,000 to 3,000,000 gals. a day.

In many cases wells and mere borings have been put down right through the chalk to the upper greensand or gault below, and have yielded only a very small quantity of water. This arises from the fact before referred to, that the water circulates freely only in the cracks and into by the boring, little water is obtained. suring a supply from the chalk, is by sinking a well down to below the permanent level of saturation, and then driving headings or adits in various directions, for the purpose of reaching some of these fissures. Many of the towns along the south coast of England are supplied by found that where the chalk of the South Downs has been undisturbed and is unfaulted, there are large vertical fissures which run, broadly speaking, from north to south, that is, at right angles to the be seen running down the beach in many on both sides which may shortly be sumplaces into the sea.

Parallel to the coast, the water is found to lie with its surface nearly horizontal, because of these permanent outlets, but on lines at right angles to the coast, the surface of the water rises rapidly inland, on a nearly uniform slope, so much so that, at six miles from the coast, it stands more than 200 feet above mean tide level. Advantage has been taken of these conditions at Brighton, and other places similarly situated, to sink wells and drive

the level of low water.

At Brighton there are two such stations, then made from 4 inches up to 15 or 18 one at Lewes-road, on the east, and another at Godstone Bottom on the west. These wells are both about a mile and a quarter from the sea, and headings are driven to a total length east and west, from Lewes-road, of 2,400 feet; and at Godstone Bottom, of 1,300 feet. In the first case, fissures are met with about every 30 feet, but as a rule these are small, and do not yield more than 100 to 150 gallons a minute. In the latter they are further apart, but some of them yield 700 or 800 gallons a minute, or over a million gallons a day. This water, being intercepted by the headings, is led to the respective wells, where, by means of suitable steam machinery, it is pumped up to the several service reservoirs supplying the different zones of the town.

The water so obtained requires no filtration. It is bright and sparkling, but of necessity hard, and although not objectionable for dietetic use, it is not well fissures, and if some of these are not cut fitted for cooking or cleansing purposes, and would be utterly unsuitable for the The most certain way, therefore, of in-manufacturing processes of Lancashire and Yorkshire, though thoroughly well

adapted for paper-making.

In addition to the chalk, good supplies of underground water are obtained in the South of England from the Hastings sands and the oolites, and in the north from the new red sandstone, magnesian works of this character. It has been limestone, and other formations; but in all cases the works required for the utilization of these sources are very similar, consisting of wells, borings, and adits, with competent pumping machinery.

Comparing very generally "abovecoast. Along these fissures the water ground" supplies by gravitation with "untravels freely, and has its outlet at the der-ground" supplies involving pumping, base of the cliffs on the coast, and may there are advantages and disadvantages

marized as follows:

"ABOVE-GROUND" GRAVITATION SOURCES.

Advantages. 1. No pumping.

- Disadvantages. 1. Distance from place to be supplied.
- 2. No filtration. 3. Softness.
- 2. Peaty stain, 3. Costly and some-what risky im-

pounding reservoirs.

4. Large works in-4. Low charges for volved to provide maintenance. water "compensation."

- Advantages. 1. Proximity of source 1. Annual charges for to place to be sup-
- 2. Low first cost.
- 3. Few structural contingencies attending works.
- 4. No filtration.

plied.

5. No Compensation for abstraction of water.

- "Under-ground" Pumping Sources.
 - Disadvantages. pumping.
 - 2. Hardness (generally.)

WATER SUPPLY FOR FIRE EXTINCTION.

BY J. H. GREATHEAD, M. INST. C. E.

When it is considered how vast is the havoc wrought by fire every year, and that we depend upon a supply of water, in all cases, to prevent much greater ravages, the importance of this subject will be at once recognized.

In London alone, it has been calculated on reliable data that the destruction of property in 1882 amounted to at least $2\frac{1}{4}$ millions sterling, and last year it was probably more; and it has been stated by a very good authority, Mr. Edward Atkinson, of the Boston Manufacturers' Mutual Insurance Company, that the losses by fire in the United States and Canada, in the five years ending January 1st, 1879, amounted to $82\frac{1}{2}$ millions sterling, while the cost of insurance companies and fire departments in the same period amounted to 55,000,000 more, or together to an average of 27,000,000 sterling per annum.

It is difficult for the mind to grasp such figures; the last, however, is about equal to the whole rateable annual value

of the metropolis.

If such losses as these were inevitable, it would be of little profit to refer to them, but it is because I believe them to be to a large extent preventable that I have ventured to bring the subject of water supply for fire extinction before you.

In the remarks which I am about to make I purpose to refer largely to the case of this metropolis, as being likely to add additional interest to the general subject, and because the reasoning which applies to this will apply in a greater or less degree to all other similar cases.

It may be useful at once to define what are the requirements necessary to cock the water from the main, or pipe,

be fulfilled in a water supply for fire extinction purposes.

In order to reduce, as far as possible, the destruction of life and property by fire, the fire extinguishing service should have at hand—

(1) A copious supply of water.

(2) In close proximity to the property.

(3) Easily accessible.

(4) Having sufficient and reliable pressure.

In nearly all cities the water supply has been introduced and distributed without reference to the fulfillment of these conditions. The quantity of water required for the extinction of fires is so infinitesimal as compared with the quantity required for all other purposes, that, except where the conditions have been naturally favorable, the water service has been introduced, devoid of some, at least, of the qualities necessary to fit it for fire purposes. The result, in such cases, has been that mechanical contrivances have had to be provided in order to make good whatever deficiencies existed in the supplies, and dwellers in cities have become familiar with fire-plugs and fire-engines.

There are, however, some cities in this country where, the conditions having been favorable, the authorities having control of the water supplies have wisely availed themselves of Nature's gifts.

The most notable instances are those of Glasgow, Dublin, Liverpool, and Manchester. In all these cases the water supply is almost entirely by gravitation, and the result is that over the greater and most important parts of the cities there is a good pressure, and a copious supply of water which has been made easily accessible by the introduction of numerous hydrants in close proximity to the property Here, then, we have, as in each place. nearly as may be, in four of the most important cities of the United Kingdom, a a fulfillment of the necessary conditions (as to water supply) for fire extinction.

An ordinary hydrant may be shortly described as a stop-cock on a water-pipe or main, to which hose may be attached for fire extinction or other purposes. for fire-extinction, without the intervention of a fire-engine, the hose will, at its other end, be provided with a branch and nozzle. Upon opening the stop-

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will issue from the nozzle as a jet. The necessary. Hydrants with a constant pressure in the main, the quantity of water available, the length of hose employed, and the size and shape of the nozzle.

A fire-plug is a wooden plug driven tightly into a socket or opening in a water pipe under the road. When water is required for fire extinction the plug is withdrawn, and the water issues from the opening, either into the street, where it pressure of water has resulted in a reis usually received by a portable tank, or duction of the losses from fire in Maninto a stand pipe inserted in place of a chester to a small fraction (viz., oneplug. It is obvious that plugs cannot seventh) of what they were before the be used where the supply is constant introduction of the hydrants. And, acwith a good pressure, and they have not cording to the report of Captain Tozer, been placed upon the constantly charged the Superintendent of the Manchester mains (the best existing supply for fire Fire Brigade, the amount of property deextinction) in the metropolis. Several stroyed has only averaged 4.3 per cent. forms of hydrants and a fire plug and of that at risk during the last ten years, stand pipe may be seen in the Water while it will be seen presently that in Companies' Pavilion in the Exhibition.

hydrant, it is necessary that the pressure In Liverpool the fire brigade is a branch

So much has been written and said tained. about hydrants, and the advantages to former over the latter are not sufficiently in the same period was £110,000, or great to justify any large expenditure about £215 per 1,000 of the population. upon them. When, however, the ques- In Manchester the supply is also by

height of the jet will depend upon the and copious supply and good pressure of water, are recognized as being incomparably better agents for extinguishing fires than fire engines, and the result of the introduction of hydrants into Manchester may be given in illustration. Mr. Bateman, the eminent engineer of the Manchester Waterworks, has stated publicly, on more than one occasion, that the introduction of hydrants with a good places having no efficient hydrant ser-In order to obtain a good jet from a vices the losses are many times greater. of water at the hydrant, while flowing, of the police. The water supply is mainshould be about 65 lbs. per square inch. ly by gravitation from reservoirs (from This will provide for overcoming the 400 to 600 feet above the low parts of friction of the water in passing through the town), and there are numerous hyan average length of hose, and will give drants. There are 3 steam and 14 mana jet about 80 feet high from an inch ual fire engines. The population in 1881 nozzle. From the elaborate reports of the chief officer of the Dublin Fire Brimiles. Of the 180 firemen, 170 do reggade, which he has kindly furnished to ular police duty. The annual cost of the me, it appears that all the fires in Dublin, brigade (average of three years, 1880-1except those extinguished by small hand 2) was £5,325, or £9 14s. per 1,000 of pumps, are put out by jets direct from the population. The average annual the hydrants, and that the prevailing number of fires in the same period was pressure is about 60 lbs. per square inch. 219, but the loss by fire was not ascer-

In Glasgow there is a good supply of be derived from their use, during the last water by gravitation; there are about twenty years, that it is hardly necessary 5,000 hydrants, and the majority of the for me to discuss their merits as comfires are extinguished direct from the pared with fire plugs. It is generally mains. There are 3 steam and 17 man-conceded that in all cases, whatever the ual fire-engines. The 66 officers and firewater supply may be, whether constant men are supplemented by an auxiliary or intermittent, high pressure or low, hy-force of 52 policemen. The area of the drants are superior to plugs as a means city is 9½ square miles, and the populaof letting the water out of the pipes. tion in 1881 was 510,816. The cost of But it has been contended that so long the brigade to the ratepayers in 1882 was as it is merely a question as between hy-£5,266, or £10 6s. per 1,000 inhabitants; drants and plugs, the advantages of the while the average annual loss from fire

tion becomes one as between hydrants gravitation from resrvoirs at a considerand fire-engines, a wider view becomes able elevation (200 feet to 600 feet above the Exchange), and there is a confire engines are retained, but are seldom the value of the property "at risk." operations beyond the city. of the population. in those three years was about £80,000, make them universal, and to dispense tion.

In Dublin the supply of water is again by gravitation, and the pressure varies area 29 square miles. The fire brigade, from about 40 lbs. to 80 lbs., being gen-numbering 1,743 officers and men, is an erally 60 lbs. when the water is flowing armed force lent by the Minister of War through the hydrants. There are nu- for the special service, and it is not merous hydrants, and though there are called out for purposes of war. There 2 steam and 3 manual engines, they do are 11 barracks, 10 steam fire, and 80 not appear to have been used in the small stations in addition to 40 lookthree years (1880-1-2), within the city. The brigade consists of 32 officers and manual fire-engines. The annual cost of men. The population in 1881 was 249,- the fire-extinguishing service is £86,600 602, and the area of the city is 6 square (average of two years, 1883 and 1884), miles, but the operations of the brigade or about £38 3s. per 1,000 of the populaare not confined to that area. The avertion; but this cost does not include the age annual cost of the brigade for ex- rent and repairs of the barracks, quar-1880-1-2) was £3,286, or about £13 3s. the Seine. The estimated annual average per 1,000 of the population. The esti- losses for the three years 1880-1-2, were mated value of property destroyed averaged £31,144 per annum, or about £125 of the population. per 1,000 of the population.

1882 and 1883) is 411,690, and the area 13 square miles. The fire brigade consists of twenty-seven officers and men, lice stations, with apparatus. One steam only in 1883. The total water supply is water. 11½ million gallons daily, with a pressure of 40 lbs. to 60 lbs. per square inch.

population, while the average annual loss stant high-pressure supply. There are in the two years was £10,931, or £26 11s. about 17,000 hydrants in the city and 8d. per 1,000 of the population, and this Two steam and five manual loss was equivalent to 3 per cent. only of

The population in 1881 was 341,—
The area of the city is $6\frac{3}{4}$ square pumped and partly by gravitation. Street miles, but the fire brigade extend their hydrants have, to some extent, been in-There are troduced. In certain cases, where the sixteen stations, and the annual cost to pressure is sufficient, they are used withthe ratepayers for the fire brigade is £3,- out the intervention of fire engines, but 547 (on an average of the three years, the water supply is not such as to admit 1880-1-2), or equal to £10 8s. per 1,000 of this being done generally. It is in-The average esti-tended, however, to increase the number mated annual value of property destroyed of hydrants to 8,000, and ultimately to or about £235 per 1,000 of the popula- with fire engines. The total daily supply of water is about 82 million gallons. The population is 2,269,000, and the outs, and there are 12 steam and 80 penses and wages (for the three years ters, &c., which belong to the Prefecture of £431,300, or about £122 10s. per 1,000

Having now described the operations, In Birmingham the whole of the water and their results in cities having efsupply is pumped, therein differing from ficient hydrant services, I propose to dithe cases already referred to; but a sys-rect attention to some of the more imtem of fire hydrants has been recently portant of the cities having no such serintroduced. The population (average of vices, and more particularly to New York and London.

In New York the water supply is very copious but it has not sufficient pressure and there are two stations and eight po- for fire purposes without the intervention of fire engines. Hydrants have, to some and five manual fire engines are retained, extent, been introduced, and, it is stated, none of which were used for fire extinc- with benefit, as permitting more speedy tion in 1882, and engines were used twice access to, and preventing waste of, the The total supply is, according to the report of the fire department, about 100 million gallons daily; the pop-The annual cost of the fire brigade to ulation in 1880 was 1,206,300, and in the ratepayers (average of 1882 and 1883) 1881 probably 1,240,000. The area is £3,250, or £7 18s. per 1,000 of the served by the fire brigade is about 39

square miles. In 1882 there were 50 engine companies, and 19 hook and ladder company stations, besides lookouts, fuel depots, and store houses. There were 57 steam fire, but no manual engines. In the period 1880-82 the average force was 939 officers and men, and the average annual expenditure was £288,190, or £230 8s. per 1,000 of the population. In the same period the average annual fire losses were £880,000, or about £710 per 1,000 of the population. The quantity of water used by the fire engines was about 40,000,000 gallons annually in the period 1880-2, or about 1-900th part of the total supply.

In London the whole of the water supply is pumped, and the average pressure is quite inadequate for fire extinction without the intervention of fire engines. A large number of observations were made all over the Metropolitan area by the Board of Works in 1876, and it was found that the average pressure was only about 30 lbs. per square inch, when there was no extraordinary draught on the pipes, such as that required for fire extinction; and it is not surprising that this should be The pressure given by the water companies is that required by statute, or, otherwise, by the customers of the companies, and even if they desired to do so it might be doubted whether, in the words of the Select Committee of 1876-7, the companies would be "justified by their constitution in incurring expenditure for fire purposes," for which purposes alone would it be necessary for them to increase their pressure.

The quantity of water delivered for all purposes is sufficient to meet the demands for fire extinction. There are, stant supply is being gradually extended as in the other places. voluntarily by the water companies. Hy-River Company, and they have on several existing state of things have not been all cases. A few hydrants have also been cally insurmountable. recently introduced by the Metropolitan

Board of Works in other parts of the metropolis.

In the matter of pressure, however, as already stated, the general metropolitan water supply is undeniably deficient. There is a copious supply of water in close proximity to the property to be protected, but it cannot be brought to bear upon a fire without the intervention of

fire engines.

The population of the metropolis in 1881 was 3,814,571, and the Metropolitan Board of Works area is about 121 square miles, including the city's one There are fifty-five land square mile. fire stations, 12 street, 127 fire escape, and 4 floating stations; and the brigade consists of 588 officers and men. annual average cost of the fire brigade for the three years 1880-2 was £99,880, or £26 4s. per 1,000 of the population. It is somewhat difficult to arrive at the value of the property destroyed by fire in the metropolis, but a calculation based upon the contributions of the insurance companies to the support of the fire brigade, and upon evidence given by Captain Shaw and others before the Select Committee on the Fire Brigade in 1877, would make it appear that in 1882 the value of insured and uninsured property destroyed by fire was probably considerably in excess of 21 millions sterling, or about £588 per 1,000 of the population. As compared with the efficiently hydranted places already referred to, it will be seen that the cost of the fire extinguishing service, and the fire losses, are very high in London. This will be made very apparent upon an inspection of the appended Table A, which gives, in addition to the cost of the fire services and fire losses in the several places referred to, a statement of what the cost according to Captain Shaw's reports, and losses would be in the metropolis, very few cases of short supply, and con- were the rates of cost and loss the same

It will be asked why the metropolis drants have been put down by the cor- should have been allowed to remain, year poration throughout the city, and con- after year, subject to the preventible nected directly by branches with the drain of wealth indicated by these figconstantly charged mains of the New ures? The reply is, that the past and eral occasions been found useful, though submitted to in ignorance or willingly, the pressure is not such as to admit but the difficulties surrounding the subof fire engines being dispensed with in ject in the metropolis have been practi-

More than twenty years ago the Select

rected attention to the extraordinary facilities for extinguishing fires then existing in Liverpool, Manchester and Glasgow, and to the efficiency and small cost of the fire services in those places; and, more recently, in 1876-7, the Select Committee on the Metropolitan Fire Brigade, having heard evidence as to the advantages of the hydrant systems referred to, recommended that hydrants should be put down in the metropolis at once wherever a constant supply was given, and that the water supply should be improved so as to give constant service everywhere and increased pressure. But it was found that to comply with these recommendations a permanent expenditure of £337,000 per annum beyond the cost of the fire brigade would be involved. Of this annual sum about £150,000 represented the increased cost of pumping Edward Easton, in 1877. alone; and since the quantity of water required for fire purposes is infinitesimal for all other purposes, it is obvious that ing expenses of the fire brigade. this expenditure of power, if the whole had to be pumped to the requisite height, would be out of proportion to the result obtained. I have made a calculation, based upon the relative quantities and upon the evidence given before the committee, from which it appears that for the purpose of discharging water through a hydrant upon a fire in this way, about 170 horse-power would be required for every gallon of water thrown. would be the attendant disadvantages that all the house fittings would have to be altered and strengthened, and the strength, and at enormous inconvenience to the householders and the traffic in the streets; and the pressure would, in the greater part of the metropolitan area, be it is certainly desirable that the pressure, inconveniently great. This proposal also involved the great disadvantage that it could not be carried out until the water companies should have been ranged under one control.

As long ago as 1862, the late Mr. James Easton, who held the view that no satisfactory supply of water for fire extinction with constant high pressure could be secured in connection with the ordinary domestic supply, proposed to lay down a completely new set of mains to made by the fire brigade to reduce this

Committee on Fires in the metropolis di- be used exclusively for fire purposes, but the cost would have been enormous. His estimate was £72,000 per square mile, and his proposal only extended to forty square miles of the metropolis. area alone would have involved an annual cost for interest and working expenses of £150,000. A somewhat similar proposal, but with the addition that the water was to be taken from the chalk formation at about 15 or 20 miles from the center of London, instead of from the water companies' mains, as was proposed by Mr. Easton, and that the supply was to be used for potable and culinary purposes after being pumped to the greatest attainable elevation, in order that it might have sufficient pressure for fire extinction purposes, was put forward by the Metropolitan Board of Works, on the advice of Sir J. Bazalgette, Sir F. Bramwell, and Mr. It was estimated that the introduction of this system of hydrants would have resulted in as compared with the quantity supplied an annual saving of £60,000 in the existscheme, involving a dual supply to every house, was taken to Parliament, but was withdrawn; and, in their annual report of 1878, the Board said that they "came to the conclusion, in view of the disfavor with which the scheme appeared to be regarded by most of the local authorities of the metropolis and others, not to bring it before Parliament again in the following session." Looked at purely And there from a fire extinction point of view, there is one great objection to all the proposals that have been hitherto made, viz., that owing to the great variations of mains and pipes would have to be taken level in the metropolis, there would, in up, and relaid of greater size and many localities, be insufficient pressure, while in others the pressure would be excessive.

In any water supply for fire purposes, in addition to being sufficient, should also be moderately uniform in the hose, whatever may be the elevation of the locality. This uniformity is practically obtained at present by the use of fire engines, but with the great drawback that the power requisite for giving the pressure is not available on the instant that the occasion for its use is discovered. The diagram B on the wall illustrates among other things the result of the vigorous efforts

the year 1870, when Captain Shaw first than London for fire extinction. began to publish the distances traveled by his engines—the distances run have tion again, is not the sole consideration; increased from 11 miles to 34½ miles (in behind that there is the question of fire 1882) per fire. The number of journeys loss, or the destruction of property by made has increased from 8,000 to 29,000, and the total distances run from 22,000 miles to 66,000 miles in the year.

According to the evidence given before Sir H. Selwyn Ibbetson's Committee in direct attention to the question of fire 1877, the fire engines were then only used for pumping at about one-fifth of the fires. If that was still the case in 1882, then it follows that for each time have already given the fire losses in four the engines were used for pumping upon a fire they must have run, on an average,

172 miles.

When it is considered under what unthe journeys are often made, some idea well as the water, is always on the spot ready for instant application. The same the population, as compared with £588, of the fire brigade service, viz., the by myself. growth of its cost from the commencement of the old fire engine establishment cordance with the facts I have stated; the brigade was under £41,000; in 1882 as each of the places considered. must not be supposed for a moment that at the same rate as New York, the cost necessary under existing conditions. the average annual cost in London in the The cost of the London Fire Brigade years 1880-2. is, thanks to Captain Shaw's admirable organization, still small, as compared has been prepared from Captain Shaw's with some other unhydranted cities. In table, already referred to, and it seems New York, as already stated, the cost is to place the value of efficient hydrantvery much greater for less than a third ing in a very striking light. From the the population and area. There the av- table referred to have been plotted the as that of London, though, on the other table (in 1877). tically unhydranted city, with half the in red. The blue line shows the cost in

evil to a minimum. It shows that since population, spends proportionately more

The question of the cost of fire extincfire, and the loss of life. Putting aside the last and highest question as being one not altogether dependent upon the extinguishing service, I propose now to losses as affected by the absence or presence of efficient hydrant services.

In describing the hydranted cities I of them, viz., Glasgow, Manchester, Dublin and Birmingham, in accordance with the published estimates, and I have shown that the losses are—in Glasgow, £215; favorable conditions, and how uselessly in Manchester, £234; in Dublin, £125, and in Birmingham £26 11s, per 1,000 of may be formed of the superiority of a the population. In the case of New system of hydrants where the power, as York the losses are published in detail, and amount to about £710 per 1,000 of diagram illustrates also another feature the loss in the metropolis as estimated

The Table A has been prepared in acin 1833. It will be seen that the growth but in order to give the figures a practihas been, and is, very rapid as compared cal bearing in the case of the metropolis, with the growth of the population. In I have added two columns which give the the first year of the Metropolitan Board costs and losses of a place having the of Works' administration of it the cost of population of London, at the same rates it was £106,552, or an increase in the pewill be seen that the annual cost of exriod of sixteen years of 160 per cent., tinction by hydrants, if it were at the while the population increased only 28 same rate as Liverpool, Glasgow, Manper cent, and the number of fires 44 per chester and Birmingham, would be from cent.; and in the year 1883, the cost had £30,000 to £40,000; and at the same further increased to over £115,000. It rate as Dublin, £50,000; while, if it were this increase is to be regarded as un-would be £886,000, instead of £99,880,

The diagram H (shown on the wall) erage annual cost for the three years, figures, giving the cost of the fire bri-1880-3, was over £288,000, and it ap- gades in a number of important towns pears to be growing almost as rapidly at the date of the compilation of the The cost in the hyhand, the population there is growing dranted cities, viz., Glasgow, Liverpool, more rapidly. Paris, also, another prac- Manchester and Dublin has been shown

TABLE A .- ANNUAL COST OF FIRE EXTINCTION, AND ANNUAL AMOUNT OF FIRE LOSSES, IN SOME HYDRANTED AND UNHYDRANTED CITIES.

Average of Three Years, 1880, 1881, 1882.

				·				
	Population, 1881.	Area, Square Miles.	Cost of Fire Brigade.	Cost of Fire Brigade per 1,000 Inhabitants.	Cost of Fire Brigade of Metropolis at same rate.	Loss.—Property destroyed by Fire.	Loss. — Property destroyed by Fire per 1,000 Inhabitants.	Loss of Property in Metropolis at same rate.
* Hydranted.								
Liverpool	548,649 510,816 341,508 249,602 411,689	8.28 9.55 6.7 6.0 13.15	£ 5,325 5,266 3,547 3,286 3,250	£ s. 9 14 10 6 10 8 13 3 7 18	£ 37,000 39,290 39,670 50,200 30,115	£ 110,000 80,180 31,144 10,931	£ s. 215 7 234 16 124 16 26 11	$\begin{array}{c c} & \pounds \\ \hline & 821,542 \\ 895,644 \\ 476,050 \\ 101,287 \end{array}$
* Unhydranted.								
London	3,814,571 1,240,000 1,269,023	121 39 39	99,880 288,190 §86,600	26 4 232 8 §38 3	99,880 886,490 145,500	2,242,400 880,000 431,300	587 19 709 14 192 10	2,242,400 2,707,150 734,300

^{*}The terms "hydranted" and "unhydranted" indicate the presence or absence in each place of a complete system of hydrants which are used for fire extinction without the intervention of fire engines.

† The cost of the Fire Brigade has been reduced from £3,616 in 1880, to £3,053 in 1882.

† A large number of fire hydrants have been put down, and some have been used without the intervention of fire engines, but the average pressure is not such as to admit of this being generally done.

§ Average of 1883 and 1884, exclusive of rent and repair of quarters, barracks, &c.

§ Average of 1880, 1881, and 1882.

a number of American cities. Paris and the one hand as Glasgow, Liverpool, London, having populations respectively Manchester and Dublin, and on the other twice and over three-fold as great as hand, as London, New York, Paris and New York, are not shown, but from the Birmingham, that it must appear to all table, and the remarks upon it it will be gathered that in both those cases the cost would be far above the rates shown by the red color, which has been extended to embrace a place of the size of New York.

In the foregoing remarks I have simply taken population as the basis of comparison between the several places. And, I do not pretend to say that there are not exceptional considerations apart from the question of water supply, such as areas, character and proximity of buildings, habits of people and so on, which would, and no doubt do, materially influence results, but the distinction beplaces is so broad and marked where the the Institution of Mechanical Engineers. places are of such different characters on It is, however, impossible, within the

that the absence or presence of efficient hydranting far outweighs any other consideration.

It now remains for me simply to add that, having for some years devoted much study to the subject, I believe that, notwithstanding all the difficulties, only the chief of which have been adverted to here, there are methods—or perhaps I ought rather to say there is a method—by which such cities as London, New York, and Paris may be efficiently hydranted at a comparatively small cost, and practically with very trifling inconvenience, which method I have already described in papers read at the last meettween the hydranted and unhydranted ing of the British Association, and before

limits of a single paper, as must be sufficiently obvious, to discuss the whole question; I, therefore, content myself on this occasion by advancing the proposition that efficient hydrants form, as far as our experience goes, the only effective weapon with which fire brigades can successfully cope with fires.

ON THE PURIFICATION OF WATER BY IRON ON A LARGE SCALE.

BY W. ANDERSON, M. INST. C. E.

In January, 1883, in a paper on the Antwerp Waterworks, read at the institution of Civil Engineers, I described the application of Professor Bischof's method of filtration, through a mixture of spongy iron and gravel to the purification of the waters of the River Nethe. The eighteen months' additional experience gained has shown that, so far as the purification of the water is concerned, Professor Bischof's process leaves little to be desired, but the working of the system has been costly, and the area of land required, as well as the quantity of iron necessary, has, in the case of the Antwerp water, at any rate, proved very much beyond the inventor's expectations.

The increased demands of the town rendered it necessary to extend the arrangements for purifying the water, and it became my duty to advise the directors of the company on the best means of

doing this.

The extension of Professor Bischof's method would have involved so great an outlay, that after trying, unsuccessfully, many experiments on direct filtration through unmixed iron at high rates of flow, I determined to adopt a plan first suggested to me some years ago by our chairman, Sir Frederick Abel, of agitating the water to be purified with iron instead of attempting to filter it. The object in either case was to expose the water as much as possible to an extended surface of iron, consequently, any plan by which the iron could be made to keep itself clean by rubbing against itself tional way of attaining this object, than of trusting to a partial filtration through a more or less spongy material.

The obstacle to trying Sir Frederick Abel's method at a much earlier date, was choosing a favorable time with respect

that a contact of about 45 minutes was necessary to ensure complete purification, and any such time would be fatal to mechanical means of performing the work. The late Professor Way and Mr. Ogston, it is true, had shown that with very finely divided iron the effect was much more rapid, but there was still a doubt about its permanence.

In the autumn of last year, a revolving cylinder, 4 ft. 6 in. in diameter, and 5 ft. 6 in. long, was adapted to try Sir Frederick Abel's system. It was fitted with inlet and outlet pipes, and with shelves or ledges for scooping up the iron, raising it to the top of the cylinder, and then letting it fall through the water.

At first I began to run water through at 12 gallons per minute, which gave a contact of about 45 minutes, but I found that at this rate the water was very heavily charged with iron; I gradually increased the quantity to 30 gallons per minute, and then found that 1.20 grains of iron were dissolved per gallon, or about twelve times more than experience at Antwerp showed to be necessary. The flow was increased to 60 gallons, and even then 0.9 grains per gallon were dissolved.

The experiment looked so hopeful that I fitted much larger pipes to the apparatus, and having made some other dispositions connected with maintaining a uniform distribution of iron in the cylinder, and preventing it being washed away by the comparatively rapid current that would be possible, I sent the "Revolver," as it came to be called to Antwerp, where it was put to work at the end of last February, and has continued to operate ever since.

The head available for forcing the water through the "Revolver" is, at Antwerp, limited to 5 feet, but by fitting very large pipes I have managed to get 166 gallons per minute through; this gives a contact of about 3½ minutes, and is so amply sufficient that I feel sure that, even for the waters of the Nethe, much less time will

be adequate.

The charge of iron is about 500 lbs., continually, would seem to be a more ra- and the quantity taken up by the water, including impurities and very fine iron washed away, during a run of thirtythree days was 0.176 grains per gallon.

By making suitable arrangements, and the belief entertained by Professor Bischof to the demands of the town, we were

able to obtain samples of water that had tion of iron upon organisms connected ferent from distilled water, the free amgallon to 0.001, and the albumenoid ammonia from 0.013 grains to 0.0045.

The "Revolver" turns at the rate of fier is mainly due, about 1 revolution per minute, and re-The quires scarcely appreciable power. area occupied by apparatus for dealing with 2,000,000 gallons per day is 29 feet by 24 feet, and it can be introduced into any existing system of filters, for by enlarging the inlet and outlet pipes to a suitable diameter, a head of some 12 inches will suffice to pass the water through.

It can easily be arranged so as to be used or not, as the state of the water to be purified may warrant, and the consumption of iron being only about 20 lbs. per million gallons is quite an insignificant expense. It will be found to remove all color from water whether caused by peat or clay, and will facilitate the action of sand filters by the peculiar curdling effect the iron has on the impurities.

During the experiments made at Erith, it was noticed that considerable quantities of gas collected in the upper part of the "Revolver." On collecting this gas it was found to extinguish a lighted taper instantly, and on analysis was found to contain only 8 per cent. of oxygen.

It was observed from the first that the animal and vegetable life which was so abundant and troublesome in the natural waters of the Nethe, lying over the spongy iron filters, had quite disappeared in the water, otherwise in exactly the same circumstances lying over the sand filters, and I always supposed that this was due chiefly to mechanical filtration through the spongy iron having separated all the germs, spores and seeds which come to life above it. But, during the recent hot weather, it has been found that the water from the "Revolver," though it contains all the impurities of the natural water, has been modified by the action of iron to such an extent that neither animal nor vegetable life is apparent over the sand filters. Without presuming to draw very wide inferences from this fact with reference to the ac-goff's Polar Expedition.

been purified by the "Revolver" only, with disease it may, at least, be pointed and after proper exposure to the air, fol- out that the absence of visible life in lowed by filtration through one of the water treated by iron on a large scale large sand filters, the result obtained has confirms, in a great measure, the experibeen that the color was very little difments of Dr. Frankland, Dr. Voelcker, Mr. Hatton, Professor Bischof, and monia was reduced from 0.032 grains per others. It is due to the last-named gentlemen to state that to his persistent advocacy the introduction of iron as a puri-It must be borne in mind that the system does not depend on filtration only, but, first, on a process of exposure to iron, which decomposes the organic matter, and kills living organisms; and, secondly, on simple filtration, which merely separates the noxious matters which had been previously attacked by the iron. The waters of the Nethe are exceptionally bad, and heavily charged with impurities, so that the test both of Professor Bischof's and Sir Frederick Abel's systems has been very severe.

> The Russian review, Russkaya Starina and the Journal of the Russian Chemical and Physical Society have lately devoted some attention to the first steam engine that was made in the Russian Empire, in 1763, at the ironworks of Barnaoul, in Western Siberia, by a mining engineer, Polzunoff. It appears from M. Wo-yeikoff's description of this steam engine, the model of which, *Nature* says, exists still at Barnaoul—both reviews have figured it on plates—that Polzunoff's engine was a reproduction of the "fire-engine" of Newcomen, with some original improvements. Thus, it has two cylinders, instead of one, and, instead of the beam, Polzunoff made use of a wheel which received the chains of the pistons, and transmitted the circular movement, transformed again into a rectilinear one, to a pair of bellows, used for blowing air into a high furnace. distribution of vapor was automatic, as in Newcomen's engine, but with several improvements. The engine, which had cylinders 9 ft. long and 9 in. in diameter, worked during two months from May 20th, 1766, and 3100 cwt. of silver ore, yielding 5 cwt. of silver, were melted with its help. But Pulzunoff did not see his engine at work, as he died from consumption four days before. He was a remarkable man for his time. In his theoretical remarks about "Air, Water, and Vapor," he notices also that physicists are not agreed as to the origin of heat, some of them seeing in it a much-divided, fine moving matter, while others "see the origin of heat in friction and in the vibratory motion of the particles inaccessible to our senses, of which the bodies are constituted." He obviously quotes here the words of Lomonosoff, who stated in these words the mechanical origin of heat in his little-known memoir, written as an instruction to Tchitcha-

SIZE AND INCLINATION OF SEWERS.

BY ALFRED EDWARD WHITE, Assoc. M. Inst. C. E.

From Selected Papers of the Institution of Civil Engineers.

There is no doubt that each of the two considered equal to the amount of the systems of sewerage, the separate and the combined, possesses certain advantages and certain disadvantages, as compared with the other; there being some conditions under which the former system may be adopted with the greater benefit, and other conditions under which the latter is the more applicable. An advantage of some importance, however, which the separate system possesses over the combined system, is that of allowing of the use of sewers of a smaller

As a rule, the smaller a sewer (within certain limits) the better, provided it is large enough to deliver the maximum quantity required to be disposed of; and the smaller the excess of the maximum flow over the ordinary flow, the more efficient may the sewer be made for the conveyance of the ordinary flow. sewage, will not, with the dry-weather flow consisting of sewage only, work as efficiently as a smaller sewer, constructed to convey the sewage with only a limited quantity of surface water. The larger sewer is so much in excess of the requirements of the dry-weather flow, that it will not under ordinary circumstances be self-cleansing to the same extent as the smaller sewer, while the smaller may also be more efficiently flushed with a moderate supply of water.

It probably is necessary in almost all cases (in order to avoid an unreasonably complicated arrangement of branch drains) to admit the water from back roofs and back yards to the sewers, even where there are separate drains for surface water; but the greater the quantity so admitted the more it will tend to neutralize the advantage above referred

To determine the volume of the dryweather flow in any sewer is a comparatively simple matter, if sewage only be

water-supply; which amount is usually known with sufficient accuracy, and for an average town may be taken at 25 gallons per head per day. In making provision for the maximum dry-weather flow of sewage, it is usual to assume that one half the daily quantity is discharged in from six to eight hours; if, therefore, the daily quantity be assumed at 25 gallons per head, the maximum flow will be at the rate of 12½ gallons per head in (say) six hours, or about 2 gallons per

head per hour.

The amount of rainfall, which it is necessary to provide for in the sewers, is a much more difficult matter to determine, and one which seems to be often under-estimated. In the first place it is necessary to estimate the amount which the sewers should be capable of receiving A above storm-overflows; and in the second sewer constructed to receive the whole place the amount which they should de-of the surface water in addition to the liver below such overflows. To prepare for the heaviest rains in this country is out of the question, considering the excessive falls which occasionally take place. The rate of rainfall to be provided for above the overflows should be determined with due regard to the degree of risk of such rate being exceeded, and to the amount of inconvenience or damage which would be caused in the event of its being exceeded; but to incur a great expense in constructing large sewers, merely to avoid the probability of their overflowing and causing a small amount of damage, once or twice in a generation, would be unreasonable. Such expense, however, might be justified where the probability of overflow, and also the damage likely to ensue, were With regard to the sewers begreat. low storm-overflows, their capacity should be sufficient to avoid overflows of such frequency and amount, as would seriously pollute the watercourses or rivers receiving the overflows.

Under the separate system the only admitted to it, as such volume may be rain which should find its way to the

sewers is that falling upon back roofs are, for the purpose required, of a more and back yards, and the quantity may be satisfactory nature than those above reestimated from the area of such roofs ferred to. "British Rainfall" for the and yards, together with the maximum year 1880 contains a very useful table, rate at which rain falls. The above area contributed by Mr. Baldwin Latham, M. may be taken at an average of 500 square Inst. C. E., prepared from the records of or 100 square feet per head of the popu-

description required to determine the maximum rate at which there is a probability of rain falling, are of a very been placed at the disposal of the author meager character. Observations of rainfall are not usually taken at shorter in- not before been tabulated, a table pretervals than twenty-four hours, and the duration and amount of most heavy rains consequently are not recorded. In the volumes of "British Rainfall," there are, however, tables giving all the exceptionally heavy falls reported by observers in various parts of the United Kingdom, and by these tables some valuable information on the subject is given. Taking the records of the three years, 1880, 1881 and 1882; there are reported fifty seven falls at a rate of over 1 inch per hour, forty-two over $1\frac{1}{4}$ inch, thirty over $1\frac{1}{2}$ inch, eighteen over 2 inches, six over 3 inches, and two over 5 inches per hour. The heaviest fall reported was at the rate of 5.80 inches per hour, and it continued for thirty minutes. Regarding these records, the impracticability of providing for the heaviest falls is obvious; it seems to the author, however that a fall at the rate of $1\frac{1}{4}$ inch per hour should in average cases be provided for, in sewers which are not relieved by storm-overflows; and for the purpose of future calculations it is assumed that such sewers should be capable of receiving a fall of this amount. It should be stated that many of the above-mentioned forty-two falls, which exceeded $1\frac{1}{4}$ inch per bour, were of such short duration that they would not cause sewers, capable of discharging this amount, to overflow, as the capacity of sewers, independent of their discharging power, is considerable.

The available statistics, of the character necessary to determine the amount of rainfall which it is desirable to provide for in sewers below storm-overflows,

Table 1, which is an abstract from the above-mentioned tables, shows the number of times certain rates of rainfall were exceeded in two years; also the aggregate duration of the falls exceeding these

Table I.

	Rate of fall in fractions of an inch per hour.	Number of times rate was ex- ceeded in two years.	duration of excessive falls in
$\left\{ egin{array}{c} \operatorname{Croydon} \\ \operatorname{Records} \end{array} \right\}$	14 16 18 112	38 78 108 154	$ \begin{array}{r} 20\frac{1}{4} \\ 45 \\ 73 \\ 115\frac{1}{2} \end{array} $
$\left\{egin{array}{l} { m Camden} \\ { m Squarc} \\ { m Records} \end{array} ight. ight.$	14 16 18 112	59 99 136 202	$ \begin{array}{c} 11\frac{1}{2} \\ 35\frac{5}{4} \\ 71\frac{3}{4} \\ 119 \end{array} $

From this table may be obtained, approximately, the number of times that storm-overflows would come into action with sewers capable of discharging various amounts of rain, and also the aggregate duration of the overflows. As, however, a number of the falls included were of very short duration, and in many cases would not be simultaneous over the whole drainage area, it may be assumed that some of them would not cause overflows, and that the duration of the overflows caused by others would be reduced; and to compensate for this a deduction of (say) 20 per cent. should be

feet for a house occupied by five persons, a self-recording rain-gauge at Croydon; such table giving the quantity, duration, lation, and it may be assumed that the and rate per twenty-fours hours, of all entire rainfall upon such area is dis-charged into the sewers. falls of rain of any importance, from March, 1879, to April, 1881. Some simi-The published rainfall tables, of the lar information is afforded by the records of a self-recording rain-gauge at Camden Square, London, which have very kindly by Mr. Symons. As these records have pared from them, giving particulars of the important falls of 1881 and 1882, is appended to this paper.

^{*&}quot;On the distribution of rain over the British Isles." Compiled by G. J. Symons, F. R. S.

made from the figures in Table 1. Now, taking a sewer capable of discharging a rainfall of 1 inch per hour, and making the required deduction, the number of overflows during two years, according to the Croydon records, would be eightysix, and according to the Camden Square records one hundred and nine, and their impracticable, the inclination should at aggregate duration, in each case, about fifty-eight hours; or during one year the number of overflows would be fortytively, and their duration, in each case, fore assumed that sewers below stormoverflows should be capable of discharg- $\frac{1}{8}$ inch of rainfall per hour.

It is of interest to notice that of the be received by sewers capable of discharging 14 inch per hour. Eight falls such sewers, forty-six of one-quarter, and one hundred and sixty-eight in excess of one-eighth their capacity. The heaviest fall, which was at Camden Square, coninch per hour; this, however, taking into consideration the shortness of its duration, was about 12 per cent. below that annexed diagram, in which the water is which sewers capable of discharging $1\frac{1}{4}$ up to A, then, according to the above inch per hour would receive. The fall rule, if the velocity of flow at A be repsecond in importance was at Croydon, resented by 5, that at B, half-way down, and continued for ten minutes at the will be about 4, and at the bottom 3, rate of 1.34 inch per hour, this being while the velocity at C, mid-way between about 30 per cent. below the amount the sewers would receive.

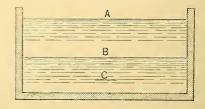
Upon the area before mentioned as that which may be assumed to be covered, per head of the population, by back roofs and yards, viz., 100 square feet, a rainfall of 14 inch would produce 65 gallons; and as the maximum volume of the sewage proper, in average cases, as already determined, is about 2 gallons per hour should be provided for in sewers which are not relieved by storm-over-With regard to sewers below storm-overflows, the volume to be provided for, per head per hour, according

of $\frac{1}{8}$ inch on 100 superficial feet, or $6\frac{1}{2}$ gallons, and 2 gallons of sewage, making 8½ gallons.

Sewers should, where possible, be constructed with such inclinations as will render them self-cleansing with the ordinary flow of sewage; and where this is least be sufficient to give a self-cleansing velocity with the assistance of flushing.

As to the velocity necessary for selfthree and fifty-four and a-half respec- cleansing purposes, authorities differ somewhat. It seems to be usually conabout twenty-nine hours. Overflows to sidered that small sewers require a this extent in most cases, and probably greater mean velocity of sewage flow to a considerably greater extent in many than large sewers, but the grounds upon cases, would be admissible, and for the which this assumption is based do not purpose of future calculations it is there-seem very clear. The bottom velocity is that upon which the self-cleansing properties depend; but how is this velocity to be determined? The size, form, gradient, and depth of flow of a sewer rainfalls at Croydon and Camden Square, being given, there are several reliable during the above period, none amounted formulas for calculating the mean velocto the maximum quantity which would ity, but not so the bottom velocity. One authority states the bottom, mean and surface velocities to be nearly as 3, were in excess of one-half the capacity of 4 and 5, and others express the ratio by figures nearly corresponding with these. It appears to be assumed that these proportions apply under all circumstances; but that this is a mistaken assumption, tinued for ten minutes at the rate of 1.68 the author would submit, may be proved as follows:

If a trough be taken, as shown by the



head per hour, a total of 67 gallons per the bottom and B, will be about 3½. Now if the water be only up to B—that is to say, of half the depth before assumed and the inclination be increased so that. the mean velocity is the same as before, then the velocity at C, it being about the to the foregoing conclusions, is a rainfall mean, will be 4. Thus in the former case

the velocity at C, which was $3\frac{1}{2}$, was less than in the latter, the mean velocity in each case being the same. How then will the bottom velocities in the two cases correspond? The velocity of the bottom water is affected by three forces: I. Its own gravity, due to the inclination of the 2. The velocity of the water directly above. 3. Its friction upon the bottom of the trough. The first force, that of gravity, is greater in the latter case, or with the shallow flow, as the inclination is greater; the second force, that of the water above, is also greater in the latter case; for, taking any point above the bottom, as, for instance, the point C, the velocity at that point is greater in the shallow flow. The third force, that of friction, upon the bottom of the trough, is equal in each case. Both the force of gravity, and the greater velocity of the water above, tend to give the bottom-water a greater velocity with the shallow flow, and it is therefore evident that the difference between the mean and the bottom velocity is greater with a deep flow of sewage than with a shallow flow, or, under ordinary circumstances, with a large sewer than with a small one. It would therefore appear that the mean velocity necessary to render sewers self-cleansing is greater with a deep flow than with a shallow flow.

It may be assumed that 150 feet per minute is an ample self-cleansing velocity for ordinary sewers when running half-full or thereabouts, and 135 feet per minute is probably quite sufficient for a shallow flow, such as that discharged in dry weather, provided the sewage be sufficiently deep to float or submerge the solid matters contained in it.

The inclinations necessary to produce a velocity of 150 feet per minute in circular sewers of various sizes, flowing half-full, or full, and in egg-shaped sewers flowing two-thirds their vertical height, are shown in Table 2; also the population which such sewers, when running full, would be capable of serving at 67 gallons per head per hour above storm-overflows, and 8½ gallons below storm-overflows.

Sewers should be constructed to flatter inclinations than the above, and these inclinations are only admissible where flushing power is provided.

TABLE II.

	Size of Sewer.		to produce velocity of 150 feet	Population served by sewers a- bove storm overflows.	served by sewers be- low storm-
Ft.	In. Ft.	In.			
0	6×0	6	1 in 174	165	1,297
0	9×0	9	" 261	370	2,919
1	0×1	0	" 349	658	5,189
1	3×1	3	" 436	1,028	8,107
1	6×1	6	" 524	1,481	11,675
2	3×1	6	" 661	2,080	16,390
2	6×1	8	" 734	2,567	20,235
2	9×1	10	" 808	3,106	24,485
3	0×2	0	" 882	3,697	29,140
3	3×2	2	" 955	4,340	34,200
			1	1	

In the preparation of the foregoing and following tables, the formulas used are those of Eytelwein, viz.:

$$V = 5604\sqrt{R} S.$$

 $S = \frac{V^2}{R(5604)^2}.$

Where V=velocity in feet per minute.
S=sine of inclination.
R=hydraulic radius.

To ascertain the gradients required for self-cleaning with the dry-weather flow, it is necessary to determine the amount of such flow as compared with the capacity of the sewers. According to the figures already given, the maximum quantity to be provided for in sewers above storm-overflows is 33\frac{1}{2} times, and in sewers below storm-overflows 4½ times, the maximum dry-weather flow. difference, however, between the dryweather flow and the capacity of the sewers would often be considerably greater than this, as sewers are of necessity somewhat larger than necessary for the maximum flow, through certain portions of their length, especially on approaching dead ends. To allow the required margin, let it be assumed that the capacity of sewers above storm-overflows is 45 times, and below storm-overflows 5 times, the maximum dry-weather Working upon these proportions, the inclinations required above stormoverflows in sewers of various sizes, to produce a velocity of 135 feet per minute with the dry-weather flow, are shown

contributing to it, the velocity when run- head per hour. ning full, and the population which the

by Table 3; also the depth of the dry-sewers, when running full, would be weather flow, the assumed population capable of serving, at 67 gallons per

TABLE 3.

Size of Sewer.	produce veloci- ty of 125 ft. per		contributing to	Velocity when running full, in feet per minute.	Population served by sewer when running full at 67 gai- lons per head per hour.
Ft. Ins. Ft. Ins. 0 6 × 0 6 0 9 × 0 9 1 0 × 1 0 1 3 × 1 3 1 6 × 1 6 2 3 × 1 6 2 6 × 1 8 2 9 × 1 10 3 0 × 2 0 3 3 × 2 2	1 in 50 " 75 " 100 " 125 " 150 " 214 " 238 " 262 " 286 " 310	Inch. 0.56 0.83 1.11 1.39 1.67 2.63 2.92 3.21 3.50 3.79	230 514 915 1,428 2,057 2,708 3,343 4,046 4,816 5,650	280 	308 691 1,229 1,919 2,764 3,638 4,491 5,435 6,468 7,590

Table 4 gives particulars, similar to the maximum flow being taken at 81 those in the preceding Table, with refer-gallons per head per hour. ence to sewers below storm-overflows,

TABLE 4.

Size of Sewer.	ty of 135 ft. per	weather flow, or of flow equal to one-fifth the capacity of	contributing to	Velocity when running full in feet per minute.	Population served by sewer when running full at 8½ gallons per head per hour.
Ft.Ins. Ft. Ins. 0 6 × 0 6 0 9 × 0 9 1 0 × 1 0 1 3 × 1 3 1 6 × 1 6 2 3 × 1 6 2 6 × 1 8 2 9 × 1 10 3 0 × 2 0 3 3 × 2 2	1 in 145 " 217 " 289 " 361 " 434 " 525 " 583 " 642 " 700 " 758	Inch. 1.76 2.64 3.52 4.40 5.28 8.79 9.77 10.75 11.72 12.70	1,213 2,729 4,852 7,581 10,917 15,577 19,231 23,270 27,693 32,502	165 " " " " " 161 " "	1,427 3,211 5,708 8,919 12,843 18,326 22,625 27,377 32,580 38,237

represents the margin allowed in deter- ing velocity. mining the amount of the dry-weather The size of sewer for inclinations

The difference shown in Tables 3 and weather flow be less than that stated, in 4 between the population contributing to which case the volume of sewage would the dry-weather flow, and the population also be less, an increased inclination which the sewers are capable of serving, would be required to give the self-cleans-

flow, as compared with the maximum other than those in the tables may easily flow, as previously explained. Should be calculated from those given, the disthe population contributing to the dry-charge being in proportion to the square disposed of.

With sewers on the combined system, quently be proportionately less.

root of the sine of the inclination. The the maximum amount of water to be sine, however, for a given population and dealt with, in proportion to the populagiven inclination, may vary considerably, tion, would probably be, in an average according to the local conditions affect- case, three times that provided for in the ing the volume of sewage per head to be tables; and the population served by a sewer of a given size would conse-

ON THE CONSUMPTION OF FUEL IN LOCOMOTIVES.*

BY M. GEORGES MARIE, Engineer of the Paris and Lyons Railway.

From "The Engineer."

During the past twenty years a great by him during the last few years, which advance has been made in regard to show an average consumption in good economy of fuel in steam engines. In locomotives of 3.35 lbs., when the horse-

marine engines remarkable results have power is measured by the work done at followed from the general use of com- the circumference of the driving wheels, pound cylinders and surface condensers; and of 2.91 lbs. when it is measured by for whereas their consumption was for the indicator diagrams; the fuel being of merly from $3\frac{1}{2}$ lbs. to $4\frac{1}{2}$ lbs. per indigood quality and the firing done with cated horse-power per hour, it has now care. Comparing this with the marine been reduced to about 2 lbs., and some- engine consumption of 2 lbs. per inditimes even less.† Equally good results cated horse-power, it is seen that locoare obtained with Corliss engines. This motives are much more economical than progress in economy of fuel has led to is usually supposed, considering that they the endeavor to effect a corresponding work non-condensing while marine en-reduction in locomotives. But, before gines enjoy the great advantage of conthe ordinary build of locomotives so long densation. The author's first experiin vogue is abandoned, their exact conments on this subject, made in 1877 on sumption ought to be ascertained. Generally it is measured in pounds per mile; the line between Rive-de-Gier and St. Etienne in the department of the Loire, but that mode is not a convenient one gave a consumption of 2.90 lbs. to 3.24 for comparison, because it takes no ac-|lbs. per indicated horse-power per hour;* count of gradients, weight of train, other experiments confirming this conspeed, and train resistance, all of which sumption were also made on a longer are so variable that the bare statement length between Alais and Langeac on the of consumption per mile is of scarcely Nimes and Clermont line. These results, any value. The only proper way of which were widely criticised, led M. reckoning the consumption, so as to admit of comparison under different cir- neering at the Ecole des Ponts et Chauscumstances, is in pounds per horse-power seés, to request that the experiments per hour; and this is accordingly the might be repeated in his presence. Fresh new methods described in the present trials, which may be considered official, paper, as applied to locomotives under were accordingly made with him on 18th, ordinary working conditions. There is a 20th and 21st of July, 1882, on the Mont general impression that locomotives con- Cenis line between St. Jean de Maurienne sume as much as from $4\frac{1}{2}$ lbs. to $5\frac{1}{2}$ lbs. and Modane, with the ordinary trains. of fuel per horse-power per hour. With a view to dispel this very prevalent error, found to be 2.90 lbs. per indicated horsethe author can quote experiments made power per hour. In these experiments neither indicator nor dynamometer of

^{*} Read before Institution of Civil Engineers.

[†] See Paper by Mr. F. C. Marshall, Proceedings 881, p. 452.

^{*} See "Revue des Chemins de fer," July 1881, p. 17.

any kind was used, such delicate instruments being liable to give rise to errors. Indicators especially occasion considerable errors through the oscillations of the piston-rod and spring, and in general give accurate results only from stationary engines working at slow speeds. The following are the particulars of the three days' trials, which it is hoped will successfully clear the locomotive from the imputation of wastefulness in consumption of fuel.

Choice of Line.—For experiments of this kind the writer generally chooses a steep rising gradient, because the work performed by the engine can then be easily and accurately calculated. It then consists of two portions: first, the work due to the train resistance on a level; and secondly, that due to gravity on the incline. On a steep rising gradient this latter portion becomes much the more important, while it can always be determined with accuracy, being the product of the total weight of train and engine, multiplied by the difference in level between the two ends of the incline; whereas the calculation of train resistance on a level is always subject to slight errors, arising from variations in the circumstances of wind and weather. Hence the steeper the incline up which the engine takes the train, the greater is the accuracy with which work done can be calculated. In this way the engine duty can practically be determined without the use of either indicator or dynamometer of any kind. The portion of line selected for the trials has the length of $27\frac{1}{3}$ miles between St. Jean de Maurienne and Modane stations on the Mont Cenis line; the gradients are 1 in 100 to 1 in 35, rising towards Modane, which is 1709ft. above the lower station; the average gradient is 1 in $53\frac{1}{2}$.

Choice of Train.—The train chosen was a passenger train starting from St. Jean de Maurienne at 12.21 noon, stopping only once on the way, at St. Michel, for three minutes, and reaching Modane at 1.25 P. M.; the average speed being accordingly 17.40 miles per hour. The writer's father, the late Ernest Marié, had eight wheels coupled, and its principal dimensions were as follows:

 $21\frac{1}{4}$ in. 26 in. Cylinders {Diameter.... Stroke..... Wheels, diameter..... 4 ft. 15 in. Heating surface Fire-box.. 104.52 2149.70 sq. ft. Tubes....2045.18 Fire-grate area. 22.39 sq. ft.
Boiler pressure. 128 lbs. per sq. in. 22.39 sq. ft.

The weight of the train, ascertained with the greatest care, was 163.58 tons, the particulars of which are given in the tabular summary appended; engine, tender and carriages were all weighed accurately on weighing machines.

Calculation of work done.—If calculated at the circumference of the driving wheels, not in the cylinders, the work done is exclusive of the engine friction, and is given by the following formula: Work done = $W \times l \times r + W \times h$. Here W =total weight of train, including engine and tender = 163.58 tons = 366,419 lbs.; l = distance run = 17.334 miles = 91,536ft.; r=coefficient of resistance = $\frac{1}{232.5}$ in the present case, or $9\frac{5}{8}$ lbs. per ton; h = height of train's ascent = 1,709 ft. The choice of the coefficient $\frac{1}{232.5}$ explained further on. Substituting the foregoing values—

Work done = $366,400 \times (91,536 \times \frac{1}{232.5})$ +1709) $=366,400 \times (394+1709)$ = 770,600,000 foot pounds.

Of this work the portion due to the resistance on a level amounts to only 394

 $\frac{394+1709}{394+1709}$ or barely one-fifth, while gravity absorbs the remaining four-fifths. Hence an error of as much as 10 per cent, in the coefficient of resistance occasions only 2 per cent. error in the calculation of the work; while even 20 per cent. error in the coefficient causes only 4 per cent. error in the result. Although, therefore, the coefficient here taken of

 $\frac{\bullet}{232.5}$ may be open to criticism, it is clear that it may be considerably modified without sensibly affecting the calculation of engine, built from the designs of the the work done. This constitutes the principle on which the author's trials have been based; whereby he has been enabled to arrive at an accurate determination of the work done, without the off at 19 per cent. of the stroke. use of either indicator or dynamometer fessor Hirsch, and M. Bazire, of the locoof any kind. method is that it applies only to moder thor on the engine. The firing was so ate speeds, inasmuch as high speeds managed as to have no coal at all left on would be dangerous on the curves of a the grate on reaching Modane. mountain line.

correctly the consumption of fuel the au- 4.49in, below the mean; the datum level thor employed a different method from in the locomotives of the Lyons Railway that ordinarily followed in locomotive being not the actual low-water line, but trials. The general plan is, after light- a mean level below which the water may ing the fire and getting up steam, to note fall without danger. The water-gauge the pressure shown by the gauge, and was of course observed while the engine the height of the water level, and to was on the level portion of the line in estimate the quantity of coal then on the station, the line running level through the grate. The trial is then made, and every station on this railway. is so arranged as to end with the same remaining in the tender weighed 1,133 pressure and water-level as at starting, lbs., which would show a consumption of and the coal remaining on the grate is 2,249-1,133=1,116 lbs., if the boiler tity consumed on the journey, adding succeed in securing the same steam mine correctly the quantity of burning sumption, to allow for the difference in the calculated consumption almost albefore and after the trip. ways involves a serious error. This is lbs., of Anzin patent fuel in bricks, and lighting the fire. cluded as fuel in reckoning the actual ordinary way, with 128 lbs. of steam, cut of lighting the fire, above the air tem-

The only objection to the motive department, accompanied the austeam pressure was then found to be 20 Consumption of fuel.—To ascertain lbs. per square inch, and the water-level again estimated. The correct consump- had been in exactly the same state after tion is arrived at by measuring the quan- the trip as before; but no skill could what was on the grate at starting, and pressure and the same water level as on subtracting what remains at the end. lighting the fire. A slight correction has Unfortunately it is impossible to deter- therefore to be made in the coal confuel on the grate; and in consequence quantity of heat contained in the boiler

Correction for difference of heat in one cause of the discrepancies met with boiler.—Calculating first the quantity of in statements of fuel consumption. In heat contained in the boiler on lighting the author's trials the above source of the fire, and secondly, the heat remaining error has been completely avoided by in it after the trip, the difference convertthe following mode of procedure. The ed into pounds of coal will be the correcengine tried had already made one jour- tion to be made in the weighed consumpney that morning, so that it was in tion of 1,116 lbs., to give the true consteam, with a pressure of 46 lbs. per sumption. Firstly, at the time of lighting square inch, before lighting the fire for the fire, when the water-gauge stood at the experimental trip. The water-level 5.16in. above datum, the quantity of was 5.16in. above the mean line. The water in the boiler would be 1,571 galfire-grate was cleared of every particle of lons, or 251 cubic feet, as ascertained fuel from the previous journey. The from the dimensions given in the tabular tender was loaded with one ton, or 2,205 summary appended. The temperature corresponding with the steam pressure 119 lbs. of wood was served out for of 46 lbs. is 293 deg. Fah. The weight The wood was in- of water, therefore, allowing for its expansion, would be 14 506 lbs.; and this, consumption, and was taken as equivalent at the temperature of 293 deg. Fah., to not more than 44 lbs. of coal; the would contain 3,436,000 heat units, recktotal supply of coal would therefore be oning from the temperature of the air at 2,249 lbs. Steam was quickly got up, the time, which was 59 deg. Fah. The and shortly afterwards the engine was metal of the boiler, weighing about 20 coupled to the train in St. Jean de Mautons, would contain about 1,175,000 heat rienne station, and proceeded thence up units. The heat in the steam may be the incline to modane. The trip was neglected. Hence the total quantity of made with the engine working in the heat contained in the boiler at the time

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perature of 50 deg. Fah., would be 4,611, water on the trip, from the tender and 000 units. Secondly, the heat remaining from the boiler, was measured with the in the boiler after the trip, estimated in greatest care, allowing for expansion of the same manner, would amount to the water in the boiler. It was found to 3,143,000 units. The difference, or 1,468,- amount to 11,290 lbs., or 8.88 lbs. per 000 units, is therefore the additional heat lb. of fuel. Deducting 9 per cent. for expended during the trip. As the weight priming, the weight of dry steam proof dry steam generated per pound of duced would be 8.08 lbs. per lb. of coal consumed was found to be 8.08 lbs., fuel. and as each pound of steam at the pressure of 128 lbs. per square inch contains analyzed of the Anzin patent fuel, which 1,169 heat units above this feed-water was used in the trip, showed 6.9 per temperature of 59 deg. Fah., the boiler cent. of ash, and 1 per cent. of moisture. would produce, in practice, $8.08 \times 1,169$ The heating power was found to be 14,-The additional expenditure of 1,468,000 means of apparatus specially made for heat units during the trip is therefore the purpose, similar to that used by coal for the trip.

Consumption of fuel per effective horse-power per hour.—The work done, corresponding with the above consumption of 1,271 lbs. was 770,600,000 footpounds. Hence the coal consumption per horse-power per hour was

$$\frac{33,000\times60\times1,271}{770,600,000} = 327 \text{ lbs.},$$

the work being the effective work, i. e., that measured at the circumference of the driving wheels. Throughout the foregoing calculation, the only coefficient open to dispute is that of the train resist-

ance, which has been taken at $\frac{1}{232.5}$; but it has been seen that even a considerable percentage of error in this coefficient would involve no appreciable error in the final result of 3.27 lbs. consumption per effective horse-power per hour. To get at the consumption per indicated horse-power per hour, it is only necessary to deduct the proper allowance for the engine friction; which has been found, in careful experiments made by the writer's father, to absorb at least 12 per cent. of the indicated power, when the engine is in perfect working order. Hence the corresponding consumption per indicated horse-power per hour would

be $3.27 \times \frac{100-12}{100} = 2.88$ lbs. as a maximum.

of dry steam.— The consumption of minutes of the trial, the engine was run-

Nature of fuel—Samples carefully =9,445 heat units per pound of coal. 600 units per lb. It was ascertained by equivalent to 155 lbs of coal, which, Ebelman, Fabre, Silbermann and Bertheadded to the weighed consumption, gives lot, in their experiments on the heating 1,271 lbs. as the true consumption of power of fuel. It consists of a glass phial, within which a powdered sample of the fuel, placed in a crucible, is burnt in a current of oxygen; the phial is immersed in a measured quantity of water, and the rise of temperature in the water indicates the heat developed by the combustion of the sample. Cardiff coal was tried in the same way by the author, and gave the same heating power; a direct comparison can therefore be made between the experimental trip and any English trials with Cardiff coal. The Anzin patent fuel is in fact composed of 91 per cent. of slack, of the same quality as Cardiff coal, and 9 per cent. of coal pitch, the heating power of which has been found by the writer to be equal to that of ordinary coal.

Remarks.—During the experiment, the admission of steam to the cylinders was for 19 per cent. of the stroke, the steam in the waste spaces being included. The valve gear was tested by Professor Hirsch himself. The locomotive had not been repaired for a long time. It may be objected that the driver probably looked after the fire much more closely than usual, being stimulated by the presence of the engineers. This may be, but, on the other side, the following circumstances were unfavorable to economy of fuel: (1) During the firing up, the locomotive gave out some heat to the atmosphere as usual; this loss of heat was equivalent to about 29 lbs. of fuel, according to an experiment made for Consumption of water and production that special purpose. (2) In the last few

ning with a very low pressure, which was necessary in order to arrive at Modane without any fuel on the fire-grate; hence the engine was working during these minutes in unfavorable circumstances.

Experiments made the 20th and 21st July. 1882.—The author, with Professor Hirsh, made two other experiments of the same kind as the first: on the 20th July, with patent fuel from the Grand Combe in the Gard coal basin, and on the 21st July, with patent fuel from La Chazotte in the Loire basin. The results were almost exactly the same as before. A tabular summary of the three experiments is appended in which all the figures may be seen at a glance. The experiments were all made with the same driver, the same engine, and the same kind of train. It will be noted that they were made in July, that is to say in the middle of summer. In winter the consumption of fuel is about 10 to 15 per cent higher, on account of the loss of heat to the atmosphere. The author considers that this loss of heat might be diminished if the clothing of the boiler were better—a point which assuredly is susceptible of improvement, especially for cold countries.

Conclusions.—The author has proved that with a good locomotive and a good driver the consumption of fuel and water is as follows:

Consumption of fuel per effective horse-horse-power per hour...........2.88 lbs. Ratio of consumption of water to consumption of fuel. . Ratio of dry steam produced to fuel consumed......8.08

Professor Hirsch attributes these satisfactory results to the following causes: (1) The total heating surface of the boiler is very large compared to the grate surface—96 to 1—so that the boiler absorbs the heat of the gases very completely; (2) the cylinders of the locomotion attained the very low figure of 2.48 tive are very large—according to the late lbs. per indicated horse-power under the M. Marie's system—so that the grade of best circumstances. expansion is high; (3) the locomotive was very well looked after, which is an ing that locomotives will not be improved important point in economy of fuel. The —in fact, he proposes to indicate furauthor may also refer to some experither on the probable directions of imments made by M. Regray, chief engi- provement; but before abandoning the neer of the Eastern Railway of France; ordinary system, he thought it would be

new system, giving diagrams at the highest speeds without the errors of the ordinary indicator. M. Regray, on this system, takes the diagrams at some distance away from the locomotive itself; the indicator is in a special van, with several dynamometers, speed indicators, &c. This van was shown at the Electric Exhibition in Paris, and obtained one of the highest prizes.

M. Regray made a few experiments on consumption of fuel in express engines hauling express trains; the result was 3.01 lbs. per indicated horse power as an average, and 2.48 lbs. as the mini-This is a very satisfactory verification of the author's result, viz., 2.88 lbs. per indicated horse-power. It is important to notice that these very close results have been arrived at by two methods as different as they could possibly be. The fuel employed in M. Regray's experiments was not patent fuel, but ordinary small coal from Bascoup, in Belgium. These satisfactory results confirm what the author's father always maintained, namely, that locomotive engineers ought to use large heating surfaces and large cylinders; he always built his own locomotives by that rule.

The author has thus endeavored to prove that locomotives are not so imperfect as engineers generally believe, as regards economy of fuel. Assuredly the locomotive is a very simple form of engine; but simplicity is of great importance with the very high piston-speed of That speed, however, is locomotives. very favorable to economy in fuel-contrary to the opinion of some engineers because it diminishes the leakage of steam and the condensation of steam during admission. A locomotive working with a very slow piston speed is not so economical as with a high speed. Express engines give better results than mountain engines, as is seen by M. Regray's experiments, where the consump-

The author has no intention of implythey were made with an indicator on a interesting to make exact experiments,

TABULAR SUMMARY OF EXPERIMENTS.

		18th July.	20th July.	21st July.
Items of experiments.	Units.	Patent fuel Anzin.	Patent fuel Grand' Combe.	Patent fuel La Chazotte.
Total distance run by train.	foot	91,536	91,540	91,540
Ratio of resistance on level to weight of train. Difference of level of the two stations	ratio foot	$2\overline{32.5}$ $1,709$	$\frac{2\overline{32.5}}{1,709}$	$\frac{1}{232.5}$ $1,709$
Difference of fever of the two stations				1,100
Weight of engine and tender (not loaded) Weight of carriages and vans (not loaded)	lbs.	125,076 204,800	125,076 225,285	$\begin{array}{c} 125,076 \\ 176,212 \end{array}$
Weight of the load on engine and tender	"	21,614	24,738	26,422
Weight of passengers and men	66	7,409	5,711	4,785
Weight of goods		4,575	4,264	3,149
Total weight of train	"	366,474	385,074	335,614
್ಷಕ್ಕು. (Patent fuel and fagots loaded on				
tender	lbs.	2,249	2,251	2,249
Patent fuel and fagots loaded on tender Pressure in boiler (above atmospheric pressure) Height of water in boiler (above water-line)	lbs. per sq. in.	46.28	21.36	18.23
water-line)	inch	+5.16	+5.24	5.08
Fuel remaining on tender	lbs.	1,133	966	1,158
Fuel remaining on tender. Pressure in boiler (above atmospheric pressure). Height in water in boiler (above or under water-line). Depth of water withdrawn from tanks during the experiment.	lbs. per sq. in.	19.65	21.36	7.83
under water-line)	inch	-4.49	+0.82	-4.73
Depth of water withdrawn from tanks during the experiment	inch	19.38	27.30	17.38
Weight of metal in boiler	lbs.	44,100	44,100	44,100
Capacity of boiler, water being at water-line.	cubic foot	217.4	217.4	217.4
Diameter of cylindrical shell. Total length of boiler.	foot foot	$\frac{4.92}{22.31}$	4.92 22.31	4.92 22.31
Distance from water-line to top of boiler	foot	0.984	0.984	0.984
Horizontal surface of tanks in tender	square foot	73.59	73.59	73.59
			1	

giving the consumption of fuel per horse- cal results in consumption of fuel with power. Comparative tests with the va- the theoretical results given by thermorious kinds of new locomotives ought dynamics. to be made, and with the same accuracy. Unfortunately different drivers, working made as regards the economy of fuel. in the same circumstances and with the same kind of locomotive, show consumptions of fuel varying by from 10 to 20 per cent., according to their skill. This is a serious difficulty in making such comparisons between various systems of locomotive.

The author will now compare the practi- 14,600 units, as stated above.

This will give the measure of the improvement which remains to be

Efficiency of boiler.—We have seen that the boiler gives 8.08 lbs. of dry steam for 1 lb. of coal, at 128 lbs. per square inch pressure. Now, 1 lb. of water at 59 deg. Fah. requires 1169 units of heat to make 1 lb. of dry steam at 128 lbs. pressure. Thus, the boiler absorbs Comparison of practical results as to 8.08×1169=9445 units of heat for each consumption with theoretical results.— pound of fuel, whose calorific power is The effi-

TABULAR SUMMARY OF EXPERIMENTS (continued).

Items of interest.	Units.	18th July.	20th July.	21st July.
		Patent fuel Anzin.	Patent fuel Grand' Combe.	Patent fuel La Chazotte.
Work of locomotive measured at circumference of driving wheels	foot-lbs.	770,600,000	810,100,000 1,286	705,900,000
Weight of water in boiler Temperature of water in boiler Weight of water in boiler Units of heat in water Units of heat in metal Units of heat in boiler, total	cubic feet degs. Fah. lbs. British units British units British units	251.34 293° 14,509 3,436,000 1,175,000 4,611,000	$\begin{array}{c} 252.04 \\ 261^{\circ} \\ 14,663 \\ 2,985,000 \\ 1,012,000 \\ 3,997,000 \end{array}$	$\begin{array}{c} 250.98 \\ 255^{\circ} \\ 14,652 \\ 2,901,000 \\ 988,000 \\ 3,889,000 \end{array}$
Temperature of water in boiler. Weight of water in boiler. Weight of water in boiler. Units of heat in water. Units of heat in metal. Units of heat in boiler, total.	cubic feet degs. Fah. lbs. British units British units British units	182.40 257° 10,637 2,135,000 1,008,000 3,143,000	223.41 261° 13,031 2,652,000 1,024,000 3,676,000	180.64 232° 10,703 1,885,000 885,000 2,770,000
Loss in units of heat Corresponding weight of fuel True consumption of fuel Consumption of fuel per effective H. P. per hour Consumption of fuel per indicated H. P. per hour	British units lbs.	1,468,000 155 1,271 3.27 2.88	321,000 33 1,319 3.22 2.84	1,119,000 123 1,217 3.40 2.99
Weight of water lost by tender. Weight of water lost by boiler. Total consumption of water. Total consumption of water per lb. of fuel. Weight of dry steam per lb. of fuel. Ash in fuel. Moisture in fuel. Calorific power of fuel.	lbs. "" "" per cent. per cent. British units	7,420 3,872 11,290 8.88 8.08 6.90 1.00 14,600	10,449 1,632 12,081 9.15 8.32 9.70 1.30 14,400	6,650 3,949 10,599 8.68 7.90 9.60 1.10 13,700

ciency of the boiler is, therefore, $\frac{6110}{14,600}$ = 0.65. That is to say, the boiler utilizes in practice 65 per cent. of the heat given out by the combustion of the fuel, and loses 100-65=35 per cent.This loss is due to the following causes: (1) Loss of heat contained in the gases escaping at the chimney; (2) loss of heat by conduction to the atmosphere; (3) loss of heat by the presence of some little air in excess of that needed for combustion; (4) loss of heat by the escape of a small portion of carbonic oxide not burned in- and engine together.—The quantity of to carbonic acid; (5) several minor work which a steam-engine can theoreti-

causes. It is remarkable that the total loss of heat should be only 35 per cent. with so many causes of waste. One of the best improvements that can be applied to locomotives is the heating of the feed water with the exhaust steam. MM. Kirchweger, Mazza, Chiazzari, and Körting have designed several apparatus for that purpose. None of them have been a practical success, but the author hopes the want will be supplied before long.

Efficiency of the locomotive - boiler

cally give out for one unit of heat* depends—(1) On the temperature corresponding to the boiler pressure; (2) on the temperature of the condenser. The maximum of work in foot pounds given

by one unit of heat is $772 \times \frac{1}{T^1 + 461.2}$

Here 772 foot-pounds is the mechanical equivalent of heat; T' is the temperature Fah. corresponding to the boiler pressure; T² is the temperature Fah. of the condenser, which in steam engines without condensation, is the temperature of boiling water; 461.2 is the number of degrees below Fah. zero of the absolute zero of thermo dynamics. Applied to the present case of the locomotive, the

formula gives $772 \times \frac{356 - 212}{356 + 461.2} = 136$.

That is to say, under such conditions, a theoretical steam engine would give 136 foot-pounds of work for one unit of heat. In practice we have seen that the locomotive gives 1 indicated horse-power per hour, or 1,980,000 foot-pounds for 2.88 lbs. of fuel, giving 2.88×14,600=42,450 units of heat. Thus the locomotive—boiler and engine—gives practically 1,980,000 =46.6 foot-pounds for one unit

42,450 of heat. The efficiency of the locomotive—boiler and engine—is, therefore,

 $\overline{136} = 0.35.$

Efficiency of engine alone.—The efficiency of the engine alone is clearly equal to $\frac{0.35}{0.65}$ = 0.54. That is to say, the mechanism of the locomotive, receiving steam and giving out work, gives 54 per cent of the work which a theoretically perfect engine should give in the same cir-The loss of work is 100 cumstances. 54=46 per cent. This is due to the following causes: (1) Loss of work from the expansion of steam in the cylinders

not being quite complete. (2) Throttling the steam, on entering or leaving the cylinders. (3) Back pressure of the steam during the return stroke. (4) Imperfection of the valve motion. (5) Condensation of steam during admission. (6) Leakages of steam, and several minor causes. Such are the many causes of the loss of work in the engine proper. The resulting efficiency of 54 per cent. is assuredly not so good as the efficiency of the boiler, which is 65 per cent.; still a loss of 46 per cent. is not very remarkable where so many causes contribute to produce it.

Comparison with a Corliss engine.— The author made a similar investigation with reference to a boiler and engine on the Corliss system, with condensation. The power was measured by an indicator; the consumption of fuel was also measured, and the results were as follows: Pressure in boiler, 5.5 atmospheres; temperature, 313 deg. F.; pressure in condenser, 0.9 atmospheres; temperature, 111 deg. F.; consumption of fuel per 1 H. P., 2.01 lbs. per hour; ratio of dry steam evaporated to fuel consumed, 9.5; calorific power of fuel, 14,500. The efficiency of the boiler and of the engine, compared with the theoretical results of thermo-dynamics, has been calculated, with the following results: Efficiency of boiler, 64 per cent.; efficiency of mechanism done, 53 per cent. These results are almost exactly the same as with locomotives, which give, as we have seen: Efficiency of boiler, 65 per cent.; efficiency of mechanism, 54 per cent. That is to say, the locomotive, compared with a theoretically perfect locomotive, is quite as good as a Corliss condensing engine compared with a theoretically perfect engine working as a Corliss engine. The author concludes that the locomotive is not so bad as engineers generally believe as regards economy of fuel. The general conclusion is that locomotives are not capable of much improvement as regards the economy of fuel, unless the pressure in the boiler can be increased. When the improvements in material and construction will allow the use of higher pressures, then a notable economy will be easily obtained in proportion to the increase in the value of the expression T_1-T_2

But in that case the author $T_1 + 461.2$ considers it will be necessary to employ compound cylinders, or more complicated valve gear in order to obtain the best utilization and highest expansion of the steam. In concluding this paper, he wishes to add his tribute of admiration to those English engineers who have

^{*} See "A Manual of the Steam Engine and other Prime Movers," by W. J. Macquorn Rankine. Lon-don, 1876, p. 343.

done so much for the existence and improvement of railways. To George are some of the most economical loco-Stephenson we owe the locomotive in motives there are. The author has, inits present form, the excellence of which, deed, made experiments, in which—on as regards the economy of fuel, is still worthy of admiration, while another eminent English engineer, Mr. Webb, is now carrying out a remarkable series of experiments, with the view of bringing it to its greatest possible degree of perfection. Having received from Mr. Webb himself details of his compound locomotive, which he has also had the pleasure of seeing at Crewe, the author is led to add here the few observations that have occurred to him in regard to this new kind of locomotive. If the boiler pressure be not higher than in ordinary locomotives, the author thinks the economy of fuel cannot be greater in the compound engine than in the best ordinary locomotives. With the ordinary boiler pressure of 9 atm., or 135 lbs. per square inch, the ordinary valve gear gives expansion enough, provided the cylinders be large enough, which is not always the case. The compound system lessens the injurious effect of the clearance spaces, and also diminishes the condensation of the steam during admission; but these two advantages are neutralized by the disadvantage of the steam being throttled in its passage from the first cylinder to the second, especially at high speeds. In other words, the consumption of fuel in a compound engine could not, in the author's opinion, be much lower than that given in the present paper, the boiler pressure being the same. This point would be readily settled by a few experiments on the consumption of fuel per horse-power per hour in the compound locomotive, including lighting up. The particular locomotives of ordinary class, with which the compound engine has been compared by Mr. Webb, appear to the author to be somewhat too heavily loaded for the best economy, their cylinders being smaller than those of the express locomotives on the Paris and Lyons Railway, which have cylinders of 19.7 in. diameter, and 24.4 in. stroke, with 6 ft. 6 in. drivingwheels. Fuel being very expensive on this line, the author's father always made his engines heavy, but very economical; and these express engines, which were designed by him and built at the

and of Messrs. Sharpe, Stewart & Co., the same kind of line, and at the same speed, and with the same total weight of train—the consumption of fuel was almost exactly the same as in the latest experiments with the compound locomotive; but he cannot look upon such a comparison as of great value, because it is impossible to estimate precisely the difference of circumstances in the two cases. The further experiments he has suggested with the compound engine seem, therefore, to be needed for a fair comparison. In his own experiments the author has found 9 atm., or 135 lbs. per square inch, to be the maximum boiler pressure for obtaining good expansion with ordinary valve gear and with cylinders of ordinary size. With higher pressures, either better valve gear must be employed, or the compound system; and the latter is considered decidedly preferable by the author, who has shown that great economy of fuel can be obtained with a higher boiler pressure. In the compound locomotive the boiler is very light and very strong; and the author looks forward to the pressure of steam being yet further increased during the next few years, without making the engine too heavy for the rails. It will then be a necessity to adopt the compound system for obtaining good expansion; and the compound locomotive, without being too heavy, will then unquestionably be much more economical than ordinary engines could be, and will be well adapted for high speeds. Goods engines of the ordinary kind are not so economical in consumption per horsepower per hour as express engines; and the author anticipates, therefore, even better results from the compound system in goods engines than have been obtained with express locomotives. The compound system with yet higher boiler pressure, will thus, in his opinion, turn out to be the greatest improvement in locomotives since the time of Stephen-

NEW first-class Thornycroft torpedo boat, for the German Government, made the works of the Paris and Lyons Railway, passage to Kiel, from London in fifty-two hours.

STORAGE BATTERIES.

From "Nature."

The importance and desirability of an | efficient and economical storage battery have been very widely recognized, but it is at the present time pretty generally felt that no existing form of storage batwhole extravagant and wasteful to an exfor their undeniable convenience. It is perfectly certain that their employment has not become at all general, and that they have failed to realize the somewhat sanguine hopes of their early promot-

It seems worth while to examine into the causes of this partial failure, and to inquire how far the evil opinion held by many practical men concerning our present method of storing electrical energy

is justifiable.

storage involves a loss of some 50 per cent. of the whole. Now all methods of storing and transmitting energy involve some loss. To say that any pareven 90 per cent. is not to condemn it There are many cases when utterly.

cipal ones may be specified.

(1) When the power of the source that every fraction of it stored is clear water power. The energy of the tides or wasted so far as human activity is concerned; if 50 or even 10 per cent. could be stored in such a way as to be conveniently available, it would be of considerable value, and any arrangement capable of effecting this storage could only with solar energy of the Carboniferous epoch has most of it been wasted; but a small we find it a useful modicum nevertheless.

(2) A second case when the advantage of storage over-balances the loss is when regularity and continuity of supply is needed, and when the source is irregular and fitful. Wind and wave power illustery is perfect, and that they are on the trate this kind of source; it is manifest that wind power has not been so largely tent sufficient to more than compensate used as it would have been, had it been steady and dependable. A practicable method of storing up its energy and giving it out as wanted would gradually cause it to be very largely employed. This case is also illustrated faintly by a gas-engine or jerky motor of any kind, and the regularity and dependableness of a storage cistern may very well make it desirable to put up with some waste provided it be not excessive. Mechanical devices for approximating to regularity, such as the use of slack driving belts, One of the main objections is that undoubtedly give rise to a waste of power, and so does any form of regulator. But in the utilization of artificial forms of power like this, questions of economy become almost pre-eminent; and wastefulticular method involves a loss of 50 or ness is here a most serious objection, and, it may be, prohibitive defect. At the same time, if the engine is liable to stop, the convenience of storage outweighs or if it is not always working, some mode the evil of waste altogether; three prin- of storing energy may be absolutely necessary, whether wasteful or not.

(3) Another case, and to some extent would be otherwise so completely wasted the converse of the last, is when the available source is weak, though congain. This is the case of much terrestrial tinuous, while the power is only needed for a short time, but during that time is of Niagara is enormous, and wholly required to be great. This is exemplified in the operation of pile-driving, where energy is stored in the slowly-raised weight to be suddenly expended on the head of the pile, also in the operation of drawing a bow; or again, when a small waterfall or steam-engine, running coninjustice be stigmatized as wasteful. The tinuously, is to be utilized for lighting during five or six hours each day; the obviously right plan in such circumfraction—probably not a millionth per stances as these is to store the energy cent.—has been saved and stored in the during the hours it is not wanted, and Coal-measures. It is possible to abuse thus virtually to double or treble the the coal for not having stored more, but power of the source while it is actually in use. Unless, however, the loss occasioned by storage were reasonably small,

there would be but small gain in attempting the process in this third case.

It is plainly advantageous to devise a method of storing that shall give out the greater part of what is put in; but we see by these examples that a reasonable loss may be more than compensated by convenience, regularity, availability and dependableness. Again, when energy has to be transmitted over great distances, it is in practice difficult or impossible to make the expenditure of energy at one end depend upon and be regulated by its consumption at the other; and so, without some system of storage, great waste will ensue during intervals of small consumption. Looking to the immense development which the transmission of energy may be expected to undergo in the course of the next few decades, a convenient and manageable method of receiving large quantities of transmitted energy, and of holding it in readiness until wanted, must be

of prime importance.

It was in view of such applications as these that the invention of the storage by Faure was hailed with enthusiasm by the highest scientific authority in Great Britain; while the public, jumping to the conclusion that a thing for which so many uses could be instantly found must needs be a profitable investment, hastened to provide money, not for commencing careful experiments and perfecting the arrangement, which would have been wise, but for manufacturing tons of apparatus in its first crude, immature, and untried form. Some day it may perhaps be recognized that because it can be shown that a thing will be extremely useful when perfect it does not follow that it has already attained that perfection, that indeed probabilities based on historical developments are enormously against such abnormal and instantaneous maturity, and that the careful nursing and rearing necessary to healthy maturity are better given in the seclusion of laboratory and study than in the excited and heated atmosphere of the Stock Exchange. It is doubtless recognized already that all preliminary operations are better conducted on a away; if any plate in a cell is inactive, it scale smaller than the wholesale manu- is better away; and if any cells of a batfacturing one. In developing a new tery are inactive, they are infinitely better industry there are scientific difficulties away. The rolling or coiling up of the to be overcome, and there are manufac- sheets being found awkward in practice

turing difficulties. By scientific difficulties we mean such as the determination of weak points, the best ways of strengthening them, and generally the discovery of theoretically the best modes of effecting the object in view; manufacturing difficulties begin with questions of expediency and economy—how most cheaply and satisfactorily to carry out the indications of theory, to obtain this or that material—and include the organization of a system of manufacture, of division of labor, of machine tools, which shall enable the work to be done with economy, security and despatch. Overhaste in the preliminary stages causes both these sets of difficulties to be tackled together, and so throws a grievous burden on both adviser and manager. All these untoward conditions have storage batteries experienced; and to say they have not fulfilled the hopes of their early promoters is no more than to say that those hopes were untimely and unreasonable, The period of maturity has been undoubtedly delayed by injudicious treatment, but its ultimate attainment seems to us inevitable; and it is at present a matter of opinion how nearly it has already been reachedcertainly great steps towards it have been made. Let us inquire what some of the difficulties encountered have been, and it will be seen that, formidable as some of them are, they belong essentially to an infantile stage, and are not suggestive of constitutional debility.

The first form of manufacture consisted in rolling up sheets of lead and composition, with trousering to keep them separate. The difficulties found were that the coatings would not adhere, but became detached in large flakes; that the trousering got corroded through and permitted short circuiting; and that free circulation of fluid being impossible, the acid became exhausted in some places and concentrated at others, and thus every sort of irregularity began. Now regularity or uniformity is of the most vital and fundamental importance in any form of battery. If any part of a plate is inactive, that part is better

held enough composition, and held it se- yet altogether abated. curely enough, to enable the trousering dispensed with. This was an evident ing. step in advance: free circulation of the liquid became possible, and could be assisted by stirring; there was nothing to corrode except the plates themselves, and the composition, being in the cells or holes of the grid, might be reasonably was not altogether belied. The adhesion position adhered extremely well and securely. The circulation of the liquid was not automatically perfect either, but mechanical agitation could be readily apconcentrated than that near the top, not by reason of gravitation undoing diffusion, which is impossible, but because during each charging fresh acid is formed, and in great part falls to the bottom in visible as to the actual behavior and appearance the grid is stronger than the middle bars, was. Every variety of extraordinary behavior which could be suggested as probcould possibly have imagined beforehand, trifle more active than the other, it is very made their appearance. The hundreds plain that the most active side will tend of tons of batteries made at this period to become convex; and buckling once doubtless enabled these unpleasant ex- begun very easily goes on. To cure it periences to be more rapidly acquired two opposite plans have been tried: one than would have been done on a small is to leave the plates as free and unconscale, but it was a costly series of experi-strained as possible, hanging free, it may ments. However, the experiments were be, from two points, thin, and with crinkmade, the public involuntarily assisted led or crimped margins to allow for exin the acquisition of experience, and, car-pansion; the other is to make them thick ing less for knowledge than for market- and strong, with plentiful ribs for stiff-

and liable to detach the coatings, flat of the public to involuntary experiments, plates came to be used, then perforated and the shock which their confidence plates, and then cast grids; these last underwent on being unexpectedly called having such large hole space that they upon to participate in research, have not

The main difficulty now experienced or intermediate porous material to be was how to keep the plates from touching. They might be put in wooden frames, or elastic bands might be stretched round each of them, and if they would only keep flat it was impossible they should touch unless the composition should drop out of the holes. Sometimes the composition did drop out expected to adhere. So far expectation of a hole, and bridge across the interval between two plates, but the more comwas not perfect, it was true, and pieces mon and more fatal experience was that of composition sometimes fell out of the plates would not keep straight. In a the holes, especially if too powerful curfew months the positives were found to rents were passed through the cell, but swell, and as they swelled to buckle—to still it was much better than it had been; buckle and twist into every variety of and if the plates were well filled, prop- form, so that elastic bands, wooden erly formed, and fairly treated, the com- frames, and every other contrivance failed altogether to prevent short circuiting. The cause of the buckling is, of course, irregular and one-sided swelling, and the cause of the swelling is apparently the plied; without it the acid near the bot-gradual peroxidation and sulphating of tom of the cells tended to become more the material of the bars of the lead grid, which occupy less room as metallic lead than as oxide or salt. As the bars swell, they press on the inclosed composition, occasionally driving it out, but more frequently, and with properly made and treatstreams. Another great advantage was ed plates universally, distending themthat some amount of inspection of the selves and stretching the whole medial plates became possible, and experience portion of the plate. The edge or frame of of the plates, began to be accumulated. and is not so easily stretched; in a good And painfully varied that experience and uniformly worked plate it does stretch, and an old positive plate is some quarter of an inch bigger every way that a new able, and a good many which no one one, but if one face of the plate is a able commodities, they expressed dis-ness, and besides to clamp them up one satisfaction at the result. Many of these to another as tightly as may be, and thus incipient difficulties are now overcome by in mechanical ways to resist buckling and the manufacturers, but the great dislike distortion. I do not know that any one

answer best, but practice is beginning to reply in favor of the latter, and well braced plates of fair thickness show no unmanageable tendency to buckle. It must be remembered that no material can buckle with a force greater than that necessary to restore it to flatness, and this force in the case of lead is very moderate. Hence it may be fairly hoped to overcome and restrain all exuberances by suitable clamps and guides arranged so as to permit flat and even growth, but to check all lateral warpings and excrescences.

Uniformity of action is still essential, especially if all the plates in a cell are clamped together. Plates mechanically treated alike ought to be electrically so treated also, and it is impossible to keep a set of plates working satisfactorily together unless the contact of each is thoroughly and equally good, so that Defects of contact have been a spray and creeping forms and concentrates on the lugs—this corroding action crawls between the clamped surfaces, graduilly destroys all perfect contact, insulation. Contacts on the negative plates give but little trouble; contacts on the positives have taxed a great amount of patience. Lead contacts "burned," i. e., melted, not soldered on, are evidently less liable to corrosion than brass or copper fittings, or than any form of clamp, but they are apt to be somewhat clumsy if of sufficient conductivity, and moreover they are awkward to undo again, and somewhat troublesome to do. However they have proved themselves so decidedly the best that now no other contacts will be used, and their re-introduction has been followed by a marked improvement in the behavior of the cells. So long as contact with one plate was better than with another, a thing quite possible to happen without any difference being perceptible to the eye, so long

could say for certain beforehand which other one or two received far more than of these two plans would be likely to their share of current, and became distended, warped, overcharged and ultimately crumbled away. If one or two plates in a cell are black, and giving off torrents of gas, while the rest are brown and idle-looking, it is pretty fair evidence of irregular and insufficient contact, or else of some great discrepancy in the age or make of the plates. This point also is one that was not attended to in the early stages of manufacture; plates were made for stock, and cells were made up with plates of all ages selected at random from the store. Directly uniformity is perceived to be essential, this is recognized as obviously bad. tended to work together should be of the same age and make, and inasmuch as keeping does not improve them, the best plan is not to make for stock, but to keep material ready, and then quickly make up as wanted. Plates in work deteriorate slowly, but they are wearing out in the each may receive its fair share of cur-fulfillment of their proper function; plates in idleness deteriorate as quickly, fruitful source of breakdown and irregu- and they are rusting out in fulfillment of Clamps and screws of every no function at all. Worn-out plates, variety have been tried, but the insidious however, are by no means valueless. corroding action of nascent oxygen ex- Lead material has a well-recognized erted through the film of acid which by price, and if attention were given to the subject, it is probable that decrepit and useless plates might be made to yield a very large percentage, if not the whole, of their original lead. For it must be and something produces almost complete remembered that plates deteriorate not by waste but by accretion: an old plate contains as much lead as a new one, but it contains it with the addition of oxygen and sulphion; no longer a tenacious coherent frame, but a crumbling mass of incoherent powder.

The age of plates is a point of vital interest, though but little is known as to the possibilities in this direction at present. A year may be regarded as a fair average age at the present time; but this is a low rather than a high estimate. Thick plates are found to last far longer than thin, which is only natural when it is remembered that the wearing out is due to corrosion, that corrosion proceeds mainly from the surface inwards, and that the internal portions of a thick plate are to a great extent protected by the mass of superincumbent material. If it was it possible for one or two plates to can be shown, as we understand it can,

remain almost wholly inactive while and (1) that the cost of materials is far more

the worn-out material has a market value liquid between the plates, but in the surnot incomparably less than the original; and (3) that the frequency with which especially each negative plate, from the plates have to be renewed is not such as liquid, and hence putting the plates a safe to cause much inconvenience; then we distance, say a quarter or one-third of an hold that the first stage of the durability difficulty has been overcome. more may be hoped for in this direction as experience increases, and it is not extravagant to hope that a well-ribbed, properly-clamped, and fairly-treated thick plate may last as long as five years be-

fore it becomes disintegrated.

statements involving periods of five any direction is easy, and accidental ob-years when no one has had the present improved form in use for so much as six but if it does it can without difficulty be ous to indulge in well-founded hopes. true, for some purposes. It is not to Many of the difficulties connected with be supposed that one type of cell will the early forms of battery were aggravated by Utopian notions concerning ininternal resistance of a cell was so beautifully small, that the manufacturers were jections, and in these places smaller and tempted to diminish it still further by more compact dynamos may be more putting the plates far too close together. An eighth or tenth of an inch interval is well enough if the plates had been hard madness to pack flexible lead plates full we can point out what is theoretically to drop out so near together as this. Security and dependableness were sacri-installation, be actually the most suitthese lessons have been profited by, and very different and far more compact form that the manufacturers perceive that con- may be quite essential. fidence and security are the first condiquite secondary consideration. Moreover, of storage batteries, like manufacturers this packing of the plates so closely did of dynamos, must be prepared with not really do much to secure the result forms suited to various needs. desired; the greater part of the resist- We have spoken mainly of difficulties.

than the cost of manufacture; (2) that ance of half run-down cells is not in the face or seum separating each plate, and inch apart, exerts an effect on the total Much resistance which is certainly far more than compensated by the ready opportunity thus afforded for access by both sight and touch. The old opaque boxes chock full of plates, with slight indiarubber bands between them, were started and left to Providence. No one could It is evident, however, that in a region see what went on, nor could one readily where pure experiment is pre-eminent, get at anything to rectify what was and where the units of time are months wrong. In the present glass boxes and years, instead of hours and days, the properly arranged on accessible shelves accumulation of experience is a slow and with only plugs or stude between the tedious process. It is no use making plates, clear vision through the cell in months. Nevertheless it is possible to seen and removed. But it must be see that the present cells are better than granted that these boxes are less comtheir predecessors; and as their prede-pact than their predecessors, and for cessors have lasted in good condition some purposes, such as locomotion, comfor a year and more, it is not presumptupactness is of the first importance. Most answer every possible demand. A dynamo to be highly efficient must have a ternal resistance and compactness. The large and massive field magnet, but in some places bulk and weight are fatal obsuitable: something, however, must be given up to secure the required lightness. and compactness, some sort of comprorigid slabs of perfect flatness; but it was mise must be effected. Just so with cells: of composition certain to swell and liable the best form, and this form may, for large stationary electric light or power ficed to a natural desire for sudden and able; but we may also see that for boats, Utopian perfection. We may hope that for tramcars, and for fish torpedoes, some

Efficiency, durability, economy, comtions of success, and that minutiæ as to pactness: it may not be possible to attain the number of noughts before the sig-nificant figures in the specification of re-be small room for discussion—but somesistance begin, though those also are of times one and sometimes another will be importance in their turn, are yet of the pressing necessity, and manufacturers

connected with the positive plates, and all cells up to the level of a few. Much have said nothing concerning the negatives. It is not that these are not susceptible of improvement, but their faults have been of a less imperious and obtrusive nature. They are not perfect, but they do fairly well, and there has been little need to worry much about them, until the extraordinary behavior of positives had been taken in hand The time is coming to atand checked. tend to these also. They fail not from exuberance, but from inertness. As they grow old, they do not swell, and warp, and burst, and crumble, like the positives, but they grow quietly hoary, and serenely decay. The composition in a wornthrough and through, but the frame remains intact, and it consequently never falls to pieces, nor does it swell. Impurities in the acid used tell upon a negative · plate—nitric acid is fatal. Acid much too weak or very much too strong is also deleterious, and idleness is bad. The difficulties connected with negatives mostly depend on their aggravating property of always requiring a quite opposite treatment to positives. The less a positive is formed and overcharged the better. A negative delights in complete formation and frequent overcharge. In recognition of this it is now customary to form them separately, and to give the negative a thorough dose of hydrogen without commencing the corrosion of the positive by an overdose of oxygen. When the discharge from a cell begins to flag, it is the resisting scum of sulphate that has formed over the negative plate which is responsible for the flagging. The true E.M.F. of a cell is wonderfully constant throughout the whole discharge; but the internal resistance is all the time increasing, at first very slowly, ultimately, towards the end, with a rush. One such run-down cell in the midst of a lot of others, therefore obstructs the current terribly. If only a series of cells could with certainty be made to work together uniformly, if a series could behave as well as some of the cells in it, no one would have cause to complain.

Through the whole history of the manufacture, from the very beginning, a few cells here and there have always exhibited astonishing efficiency; the aim of manufacturers may be said to be to bring

progress in this direction has been made, and it may be very fairly expected that, as uniformity is gradually attained, a series of cells subjected to the same treatment may behave in the same manner. Whenever this is certainly accomplished, there will have been reached a high stage of efficiency, beyond which further progress need be only in the improvement of comparably insignificant minutiae.

The subject of the electrical storage of energy is really one of national importance; it is comparatively a small matter whether this or that form of storage, or this or that company of manufacturers, succeeds in bringing out the out negative consists of white sulphate permanent form. It sometimes unfortunately happens that enterprising pioneers only clear the way, and retire just in time for other men to come in and reap the fruits of their labors. So much capital and so much labor have been already expended in the effort to bring storage batteries to perfection, so great progress has been made, and so apparently small are the steps which yet remain to be accomplished, that we may surely fairly hope that some of the original believers in their great, and as it seems to us inevitable, future may yet live to see their faith justified and their patience rewarded, and may even taste some of that socalled "substantial" reward without the hope of which great commercial enterprises would never be undertaken, and modern civilization would have scarcely yet begun.

> The following is from a German patent, No. 20,939, for a method for the manufacture \perp 20,939, for a method for the manufacture of artificial gutta-percha: About 50 kilos. of powdered gum copal, and from $7\frac{1}{2}$ to 15 kilos. of flowers of sulphur are under continual agitation heated in a boiler with double the quantity of turpentine or with from 55 to 62 liters of petroleum to a temperature of 126 to 150 deg. C. till completely dissolved. The mixture is then allowed to cool down to about 38 deg. C., when a solution of 3 kilos. of caseine is added, the latter being dissolved in weak ammonia with the addition of a small quantity of alcohol and wood spirit. The mixture is now heated for a second time to the same temperature until it assumes the consistency of a thin fluid. It is then boiled with a solution containing from 15 to 25 per cent. of tannic acid—galls or catechu—to which ½ kilo, of ammonia has been added. After having been boiled for several hours the mass is allowed to cool, washed with cold water, and kneaded out in hot water. After this treatment it is rolled out and dried.

NOTES ON THE CONSTRUCTION AND EQUIPMENT OF NARROW-GAUGE RAILWAYS.

By A. L. REED, Chief Engineer P. H. & N. W. R. R. Port Huron.

Transactions of the Michigan Association of Surveyors and Civil Engineers.

pare a paper on narrow-gauge railways I as to cost, that will not apply equally well to any railway, that I will simply note a few points on their construction and equipment in general, and then give you, somewhat in detail, the various items of cost particularly applicable to narrow-gauge roads, hoping they may be at least interesting to the members of the association, though I do not think they will be particularly instructive to those whose experience is largely in railroad work.

Location.—The question of location I need not allude to, except to refer you to the able paper on the subject read by Mr. Hodgman at your last meeting. treatment applies as well to roads of one gauge as another. I will say, however, that curves and grades on narrow-gauge roads are just as objectionable as on any road; although sharper curves may be used, they should be avoided as much as possible.

Supposing our location to be completed, and grades established, we are ready to proceed with construction work; we will also suppose that the contract is drawn in proper form and the work let, subject to the proper specifications, as we are dealing more directly with the work of the engineer and the contractor.

bed; clearing should be done the full may be, and all the logs, brush, and marked not simply +50 but 79+50. so as to be out of the way of the workmen as well as the contractor; as instances have been known where contractors have been tempted at least to use the of way, for making the road-bed, which is engineer should furnish the contractor, or grade; this should be done not only

When asked by the committee to pre- for use in clearing, notes of stations between which grubbing should be done, consented; but, on looking over the and width of grubbing, so that he may subject, I find so little to be said, except do no useless work and may do grubbing in connection with clearing, as a standing tree is much easier to grub out than a stump. All stumps and grubs should be taken out where the sub-grade line is within two feet of the surface, also on all cuts. Where the fill exceeds two feet low chopping will suffice, and in fills of four or more feet, stumps of ordinary height are not very objectionable and may be left standing, except where they are very large and decayed, when they should be removed.

Cross-Sectioning.—Clearing and grubbing completed, the engineer is ready to do his cross-section work, which consists in putting in stakes every 100 feet, or oftener if the surface of the ground is uneven, which stakes are set one in the center and one at the edge of each slope. Each stake should be plainly marked on one side with the number of the station at which it stands, and on the other with the cut or fill to sub-grade at the point where it stands. They should be set uniformly, the center stakes exactly on the center line, with the station number facing the backward direction of the line, and the slope or side stakes set at right angles to the line even with the center stakes, with the cut or fill facing the line. On uneven ground, plus or partial sta-Clearing and Grubbing.—The first tions should be put in in the same manwork to be done is the clearing of the ner as the regular stations, and the full right of way and grubbing for the road station number should be put on each plus stake; thus a cross section midway width of the right of way, whatever that between stations 79 and 80 should be perishable matter be piled and burned, little care in this direction will save a great deal of annoyance and time in subsequent work when stakes are knocked down by careless workmen and have to be replaced, possibly when the notes are logs, stumps, etc., lying along the right not at hand. At every point where the grade and surface lines cross, there not desirable except in special cases. The should be set a grade stake marked 0.0 at the center but on each slope, and the plus station at which each occurs care-

fully noted.

Each cross-section should be carefully recorded in a cross-section book: the usual form being to place the center cut or fill in a central column, and left and right slopes in a column at left and right of the center in the form of fractions, with the cut or fill as the numerator, and the distance out from the center line as the denominator, with their respective signs, plus for cut and minus for fill, thus:

L. C. R.
$$\frac{-2.0}{9.0}$$
 $+3.5$ $\frac{\div 3.6}{13.4}$

showing a cut of 3.5 at the center, a cut of 3.6, and a distance out of 13.4 on the right and a fill of 2.0 with a distance out of 9.0 on the left. These distances apply to a road-bed of 12 feet on fills and 16 in cuttings with a slope of $1\frac{1}{2}$ to 1.

Experience has proved that there is no economy in building narrow road-beds. We commenced on the Port Huron and North-western Railway by making fills 8 feet at sub-grade and cuts 12 feet; then we widened banks to 9 feet; on our next work we made banks 10 feet and cuts 14, and now build banks 12 feet and cuttings 16 feet, which are none too wide, and are found to be more economical in the end.

As I believe the papers which are read from time to time before this association are intended to be of practical use to the members, rather than finished literary or scientific productions, let me give what I consider the best method of doing crosssection work. I have noticed that beginners almost universally use the cumbrous method of figuring out each station by itself from the height of instrument and grade height, a tedious as well as unnecessary work. First, set your level firmly, and in such a position as to command a good view of your work; bring it to a level, and take from the nearest bench mark a reading, which add to your bench height to give you the height of instrument. Now, from your cross-sec-

the reading of your rod at that station held at grade, and the difference between it and the actual reading at the point will

be the cut or fill at that point.

Your bench-height is To illustrate. 80.10; your rod on bench mark reads 5.08, making height of instrument 85.18; your grade height at station 79 is 82 00; so your rod held at grade at station 79 should read 3.18. But suppose it actually reads 5.30; then your fill is 2.12; if it reads less than 3.18 you have a cut. If you are working on a level grade, all your grade readings will be the same, and you have no trouble; but if, for example, you are working on a down-grade of 26.4 feet per mile, add to your rod 0.5 for each station, which would give you 3.68 at station 80, and the difference between that and the actual reading will give you the cut or fill. Then you can keep on adding to or subtracting from your rod reading at grade the change for each station, and work from rod readings at grade entirely, paying no attention whatever to your height of instrument or grade height until ready to move your instrument, when you begin over again. this way one can soon become so familiar with the work that he can call off and record his work as fast as a rodman and two smart men can measure the distances, mark and drive the stakes.

In cross-sectioning at changes of grades, especially when the changes are abrupt, vertical curves should be put in, extending from 1 to 3 or 400 feet each way, so as to avoid bringing the connecting grades to a point. This introduction of vertical curves is very little extra trouble in connection with the other work and should not be neglected. It is also advisable, though not a necessity. to put in at each regular station, where fills are to be made from side ditches, berm stakes the specified distance out from the slope stakes, as workmen are less liable to cut away the berm if stakes are driven for them to work to.

Earthwork. — Cross-sectioning being done at any given point, the work of grading may be commenced. I have known of grading being begun without any cross-section work, or even the cention book, note the grade of the station ter stakes being in, but cannot say it at which you propose to commence your was a success. Fills should be made work. The difference between your in- from the adjoining excavations within an strument height and grade height will be economical distance for hauling, which

formly from the bottom from full width, so as to prevent sliding or uneven settling. Fills made from cuts by the use of dump-cars can be carried up uniformly by shifting the track as may be required; where fills are made from side ditches the latter should be taken out continuously so as to make clear waterfoot vertical, although varying circumdesirable. In cuts, the slopes should be smoothly dressed and uniform; in each cut, however small, there should be side ditches to carry off the rain-water, or that which soaks in from the sides; the ditches should have a surface width of one-half the difference of the width of cut and fill at sub-grade, leaving, as it were, an embankment through the cut, so that, when the earthwork is completed, the grade presents an unbroken surface of uniform width. It is not always advisable during the process of construction to take out cuts to the full width, or even down to sub-grade; when the material may be used for ballast the cut may be gulleted or taken out just wide enough to admit the passage of a train, and with slopes of $\frac{1}{2}$ to 1, or even steeper, if the material will allow, and the remainder of the cut taken out with trains. In certain cases it is advisable to build narrow banks at first, to be widened later on.

Across all swamps and marshes soundings should be taken to determine the nature of the ground and the depth to firm bottom, and, in case the foundation is not good, some means should be taken to improve it. Where it is not too soft or too deep, a good method is to corduroy with timber laid cross-wise of the road-bed with brush thrown on; the length of the timber necessary may be judged from the nature of the ground and the weight of embankment to be built. In some cases it is necessary to drive long piling, and some swamps are

distance varies with circumstances. The may be obtainable to make a bank. embankment should be carried up uni- have recently, in my own experience, met with a swamp $2\frac{1}{4}$ miles across, which was, in the direction of the line, a level surface; soundings showed a firm bottom 6 to 18 feet below a fairly firm muck; but the season was very wet, and an attempt to throw up a bank of muck was a failure, as it would run off a shovel before it could be thrown up. In this case I took ways where necessary. The usual slope the small poles and brush from the right given to ordinary earthwork of sand, of way and laid them along the center clay, or loan, is $1\frac{1}{2}$ feet horizontal to 1 line cross-wise, and then some small of way and laid them along the center poles, from 2 to 6 inches in diameter, stances may make a greater or less slope lengthwise, so that they would come under the ties outside the rail; on these I laid the ties and iron for a good share of the distance across the swamp, with no earthwork whatever. After the track was laid across (it was not very smooth however), we turned back and filled with clay and raised the track; soon it will be one of the best pieces of track on the road.

Culverts.—During the process of locating and constructing, the engineer has looked over his line and its contiguous territory closely, to determine the location, size and character of the necessary water-ways, and during his cross-section work has probably staked out his drains, culverts and bridges, made out his timber bills, and made provision for the timber and material for the various structures. In places where there is but a small area of surface drainage, and no danger of an accumulation of water, a small drain of sewer pipe may be made, or in cases where cheapness of construction is necessary, which too often happens, a simple box of plank, spiked together, will answer where the embankment is light. Where there is much water a culvert should be put in. On new work in new countries wood is almost entirely used, leaving the more expensive as well as more desirable stone and iron structures to be put in when the first have had their day, and the other can be brought to the spot by train, and the company have presumably more means to do work with.

Ordinary culverts are built of $12'' \times 12''$ so deep that it is almost impossible to timber; I use 10"×12" on edge, the build across them with any reasonable sticks laid one upon the other, secured expense, such places should be avoided by dowel pins. The foundations are if possible. Across some swamps and usually ordinary mudsills of flatted timmarshes very little or even no material ber, sunk in the ground below the bottom of the waterway, to avoid undermining. stakes should not be less than 2 inches The sills should be boxed down at the square, well driven, left 6 to 8 inches ends for a couple of inches to prevent above the surface of the grade, and havthe wall sticks from sliding in from the pressure of earth behind them. The top wall piece of an open culvert should be 4 feet longer than the width of embankment of sub-grade, and each succeeding stick 3 feet longer than the one above it till the surface of the ground is reached. The walls should be braced against the thrust of the earth behind them by struts across from one wall to the other, usually dove-tailed into the wall sticks. Culverts should be laid out so as to have the top of the walls reach just to sub-grade; on these walls are laid the track-stringers, lying loose so as to be brought to the required line or shifted at any time. When open culverts are more than 8 feet wide they should be made with a bridge top, i. e., with ties across the stringers. Box culverts are made as above described, but are covered with either plank or timber, and usually with the earth of the fill. Across small streams the ordinary pile bridge is the cheapest and best to build. Use white oak piles, not less than 10 inches in diameter at the small end, well driven; the usual plan has 4 piles in a bent, the bents from 12 to 16 feet apart (14 feet is a good distance), the piles sawed squarely off and the cap securely drift-bolted on top of the piles. Where the height does not exceed 12 or 15 feet the piles may answer as bents, and the track-stringers be laid directly on the caps; but where the height is greater there should be trestle-work on top of piles. Across larger streams, or where there is danger of freshets, ice, driftwood or logs, there should be a clear span to leave the channel unobstructed; on navigable streams a draw-bridge becomes For ordinary trestle-work, necessary. timber of the following sizes may be used: Caps 10×12 , main posts 10×10 , batter-posts 8×10 , stringers 7×14 , latdimensions will suffice for narrow-guage roads using engines of 18 to 20 tons of the usual standard size.

Track-laying.—In advance of tracksolid stakes for track centers.

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ing a tack or nail showing the exact line on the stake. On tangents center stakes 200 feet apart will suffice, but on curves they should be put in every fifty feet. Centers should be put on all culverts, and at intervals of 10 to 20 feet on all bridges. We will now suppose the centers in, the material all ready, our forces and construction trains at hand, and will proceed with work. First, we must load one train with the proper proportion of iron, ties, bolts, straps, spikes and tools; the car for bolts, straps, spikes, etc., is usually the head car, then come the ties, then the iron. The train is backed out to the end of the iron, and when the track-laying force is ready, as many rails and ties as will make a lorry load are thrown off, together with the necessary spikes, bolts and straps, and the train pulls ahead out of the way. The lorry men run their car back and load, say, ten rails; above the rails, but placed so as to leave the rails loose, are loaded a sufficient number of ties for as much track as the rails will lay, and bolts, spikes and straps enough for ten joints. Then the lorry is run ahead to the end of the rails, where the men, standing in a row on each side, pass forward the necessary number of ties for a rail length, laying them evenly and properly spaced on the grade, being guided by a line stretched along the grade and a pole properly spaced; a large tie should always be selected for the joint. Next, on each side, the forward gang grasp the end of a rail and pull it forward, and, as the rear end drops from the lorry, it is caught by the rear gang and placed at the end of the rail in the track, then the forward end is dropped to line; this is done on each side simultaneously; the lorry is then run ahead to the end of the two rails just laid and the process repeated. eral braces 6×6 , sway braces 3×10 , girts While this work has been going on, 6×6 , ties 6×8 , guard rail 6×6 . These another lorry load of iron and ties has been loaded and brought forward, the empty lorry tipped on its edge off the weight; we have latterly built our bridges track to allow the other to pass, which, in its turn is unloaded and sent to the rear for another load. For laying light laying the engineer should carefully re- rails three men at front and two at rear trace his line along the grade, and put in on each side is force enough; for heavy These iron more are necessary. As the iron

and ties have been run out from the lorry a pair of straps, with the necessary bolts, has been left at each joint, and two spikes dropped at each end of each tie.

Immediately in the rear of the lorry come the strappers, who quickly place the fish-plate, or whatever joint fastening may be used, on the joints, and bolt them to place, leaving the proper expansion at each joint; then come the spikers, working two together, the two on the line side ahead, spiking usually the joints, quarters and centers. Before the train is run upon the track each rail is spiked to the tie exactly to a line which a boy has previously chalked on it a certain distance from the end, measured by a short stick, so that when the rail is full spiked and lined, the line end of the ties are in a true and even line. The rail joints should be kept exactly opposite to each other, except on curves, when joints should be opposite centers on narrow-gauge track, as it thus retains its alignment much better. Two spikers are also at work on the other side, using a gauge, and quickly spiking the rail to place; each set of two spikers have with them a nipper, or a man with a light iron bar and a block of wood, whose duty it is to hold the tie to the rail while being spiked. Spikes should be driven squarely into the ties so as to have a firm bearing against the rail, both on the side and head of the spike, and should be driven, not in the center of the tie or exactly opposite on the side of the rail, but one a little ahead of the other, but both inside spikes should be driven alike, i. e., either ahead or back of the center of the tie, as it prevents the tie from rocking, which it will do if spiked otherwise. As soon as the track is laid and spiked at the joints, quarters and centers, the train may be run up and kept closely following the workmen. Behind the train come the back spikers, who complete spiking, and then the liners, who throw the track into line, when it is ready for the ballast train. Track-laying is often partially done by machinery, by means of adjustable rollers fastened to the sides of the car, on which the iron and ties are carried to the front along the side of the has its advantages, especially where men are scarce.

Ballasting.—As soon as the track is laid the engineer should run his ballast grades, which should be marked by good stout stakes set at the side of the grade, at the foot of the slope of the ballast opposite the center stake, and driven so that the top of the stakes should be as high as the top of the rail at final grade; stakes 200 feet apart on tangents and 50 feet on curves, the same as centers, will answer. The ballast train should consist of as many flats as can be conveniently used and handled, varying with the condition of the pit for loading, the capacity of the engine for hauling, and the force used to do the work. The most economical method, when a convenient pit of material is reached, is to lay a temporary track (or, what is better, if it can be done, two tracks into it, by which much time will be saved in shifting trains), then load one train while the other is on the road. Unloading is most economically done under ordinary circumstances by means of a plow worked by a wire cable from the engine, when no time is lost by men riding back and forth between pit and unloading point, as the train force is sufficient to handle the plow, and the pit force can be adjusted so as to load while the train is making a trip. An estimate of the quantity of ballast to be used should be made, so that the trainmen may make a proper distribution of it. Allowing the surface to be uniform at sub-grade, the quantity of ballast to raise the track to final grade can be determined very closely and distributed accordingly, so that, when the surface is complete, very little or no ballast will remain unused.

In raising track it should first be lifted to final grade at each grade stake and securely packed; then by use of sighting boards, the joints and centers between the two points are raised to the same grade, except on the vertical curve before alluded to when the intermediate points should be rounded to agree with the curve. On horizontal curves the outside rail should be raised; on 3foot gauge we raise the outer rail 3 inch for each degree of curvature up to 5°. All points of the track having been train; also by a lorry car running on a raised to the proper height, and the baltrack on the supply train. Each method last shoveled in and well tamped the entire length of each tie, the track is ready for lining. A liner and three or

more men with lining bars throw the the engineer, such as water stations, pastrack carefully to the exact center as indicated by the tack head in the stake driven before track laying; then all parts of the track are thrown to correspond, supply for engines. During construction and the rail brought to a true line. One work, the engines may be supplied with side (it is not essential which) should be taken as the line side, and all lining of ties, iron, or track be done on that side. Following the liners come the finishers, who properly distribute what ma terial may be left by the surfacing gang, and give the required surface to the ballast, dress it up neatly, remove any ballast from the ditches in cuts, and gather up in shape for removing any surplus material. Different companies have different forms of ballasting and dressing. Some raise the ballast nearly as high as the top of the rail in the center and slope it to the lower edge of the tie at the end; others keep it nearly level with the top of the tie in the center, and nearly as high at end of the tie, and others still have other forms; but on narrow-gauge track it is essential that plenty of ballast should be at and against the ends of the ties, otherwise it will be very difficult to hold the track in line.

been alluded to at all, although they all have an important bearing upon the work. We have not mentioned at all what is important, especially to the contractor, monthly and final estimates, also the manner of making them, building of bridges, crossings, etc., and the thousand 8"×8" caps; on them rest the floor joists, and one other matters that enter into and on the joists directly the bottom

the work of construction.

road-bed and track as completed, ready from 20,000 to 30,000 gallons, should be for the running of regular trains, and made of 3-inch staves and bottom. To mention some of the necessary equipment make the tanks frost proof, all that is for doing business. Of first note is the necessary is to put in a ceiling 18 inches rolling stock, consisting of locomotives, below the top of the staves, and pack it passenger coaches, baggage, and express with 18 inches of good sawdust, leaving cars, box cars, flat and stock cars. The the space between the top of the staves locomotives should, of course, be adapted and roof, which should be perfectly tight, to the service for which they are intend- as a dead air space; also to pack it well ed; those for the passenger service around the supply, waste, and delivery should have a larger wheel and quicker pipes and under the floor; in extreme motion than those for freight; so of the cold weather it will of course freeze a other rolling stock, it should be adapted little, but not enough to do any damage. to the class of business required; but I There are many different methods of supleave the subject of rolling stock for plying the tanks with water; that most some one better acquainted with it than in use is by a small steam pump; wind I am, and mention briefly some of the power is also quite extensively used and

senger and freight buildings, shops, engine houses, turn-tables, etc.

About the first essential is the water water pumped by hand directly into the tender tank, or better still by a small steam pump, which may be shifted from point to point, or yet again by a steam siphon and hose carried with the engine, the hose of which can be dropped into any convenient ditch or pond of water by the roadside; in case of emergency, water may be bailed up with pails. All these processes are slow and tedious, and will not do for permanent use. should be chosen at convenient points, at stations or regular stopping places, not exceeding 20 miles apart—15 is better and tanks of sufficient capacity put up. Tanks of from 20,000 to 30,000 gallons' capacity will answer where traffic is not very heavy, or even less would do, but small tanks are not advisable, as the supply is not as lasting, and in severe weather is more liable to freeze. The tanks should be erected upon a framework of posts of convenient height, so Very many points of work have not that the drop pipe will have a good sharp incline when water is being taken. For a tank of 20,000 gallons 12 posts 8"×8" in size are sufficient; the foundation may be of stone or of piles capped with 8"×8" for sills, the posts framed into them, and capped at right angles to the sills with of the tank, the joists being cut away for Equipment.—But let us consider our the chime of the staves; a tank holding equipment which more directly concerns is considered quite economical, although

my experience has been that it lacks in that respect and is not altogether reliable. Hot air engines are also somewhat used, and I believe are considered economical and reliable. Our company have had one in use at Vassar for the last six or eight months, and are well pleased with its performance thus far. Too much care cannot be taken to have good water and a supply that is permanent. Soft water from streams is considered the best; water containing minerals, especially lime and other substances that coat boilers, should be avoided.

Station buildings come next in importance to water stations, if indeed any gradation in importance can be made; for successful and economical operating all are required. It may be supposed that, during the process of construction, the location has been chosen and the grounds secured. Usually, during the first excitement of the enterprise and the rivalry of the different centers or villages in their efforts to secure the road, a choice of location can usually be had, which should be made with reference to the convenience of access, and economy and convenience of laying out the sidings and arranging for the business of the company. It is well to secure ample room at first, for, after the grounds are once secured, it is strange how soon contiguous property appreciates in value, and often it is impossible to obtain more room without buying at exorbitant prices. The station building should be of sufficient size to accomodate the business of the place. In small places, where one man does all the work, I think it advisable to unite the passenger and freight buildings in one, as it is more economical as well as convenient. For places of only a hundred or two of population, where business in terests are not very great, I have found a building 16×40 feet in size to be ample.

A convenient one is built as follows: 16×40 , with 12 foot walls, the interior divided in the middle by an ordinary studded partition, making the freight room 16×20 , and 16×20 for a waiting room and office; the office is made by running a lattice partition across from floor to ceiling, 6 feet from the end of the room. This lattice partition allows the waiting room stove to do duty for the office as well,—another item of economy, as you will please bear in mind that I am

speaking especially of the equipment of a narrow gauge road, where cheapness and economy are a desideratum. In front of the office is a bay window, so that the agent or operator has full view of the track each way. In front of the building the platform should be not less than 12 feet wide; we build it I foot above the rail with a raised portion 8 feet wide in front of the freight room, and raise the freight room floor above the waiting room floor so as to be on a level with the floor of a box car; the platform across the end and rear of freight room is level with its floor and descends again to the level of the waiting room by an easy incline. For a place of several hundred inhabitants, we build a station 20×70 feet in size, similar to the former with the addition of a baggage room; and in large places make them 20×100 feet or more. Where two waiting rooms are needed we build the office partially between the two, so as to give convenient access to both. We have found the system of passengers and freight in the same building to work satisfactorily, having in no case, except at terminal stations, any other arrangement, although in very large places it would not be desirable. During construction the engines are usually left standing out of doors with no covering whatever; sometimes a rough temporary shed or engine house is built; but it now becomes necessary to have permanent buildings for them. Such are usually built in a partially circular form, with stalls or divisions to accomodate one engine each. A suitable location is chosen, and a turntable put up, and, radiating from it as a center, the tracks enter each division of the engine-house; underneath each track, inside the house, is built a pit for convenience in working at the under side of the machinery. These houses are usually built of either brick or stone, although cheapness of construction being often demanded, wooden ones may be built with simply a frame work of $8'' \times 8''$ posts, with $8'' \times 8''$ caps, $2'' \times 6''$ studding, $2'' \times$ 10" and 12" joists; they should be sheeted around the outside, then papered with heavy building paper, then boarded and battened. Double doors in front of each division may be built on a light frame of $2'' \times 4''$ in the same way; a tar and gravel roof will do as well as any. At terminal

kept for yard or other service a small building of sufficient size for the required service should be built, and may be located over an ordinary spur track in a convenient place. At headquarters, in connection with the engine or round-house (as it is usually called from its partially circular form), should be the repair and machine shops, the size, equipment, and capacity of which will depend on the number of engines to be kept in repair, and the amount of work to be done; the more complete they can be made as to machinery and appliances, the more economically can the work be done, although of course due regard must be had to the means to do with. It is also necessary to have car repair shops and a place for storage of coaches when not in use. A supply depot is almost a necessity on a road of any importance. It is also necessary that a road should be furnished with the necessary sidings at different points along its line, and yards at terminal and important points for the storage of cars, etc.

Cost.—I am aware that I am already making this article too long and am only touching upon a point here and there, so perhaps I had better close by giving an estimate of the various items of cost that are applicable to a narrow gauge road, as very little of what I have already said will not apply to any gauge of railroad. First the right of way must be secured, which, through a farming and timbered country, like the lower peninsula of Michigan for example, will cost from \$20 to \$50 per acre, although usually from one-half to three-quarters can be secured as a donation. However, we will say an average of \$40 per acre, which gives, for a right of way 4 rods wide, 8 acres or \$320 per mile. Clearing through the average country above alluded to can be done for \$25 per acre, or \$200 per mile, and grubbing will average perhaps \$100 per mile, though in heavily timbered land it will cost very much more. A fair price for ordinary earthwork is 25 cents per yard, and at 5,000 yards per mile, (although on the P. H. & N. W. Ry., of over 200 miles, the average has been less than 4,000 yards per mile), we shall have for earthwork \$1,250. Bridges, if not too expensive, may be figured \$200 per mile and culverts at \$100. This will give for right of way and road bed as follows:

V	-GAUGE RAILWAYS. 493
	Right of way \$320
۱	Clearing 200
1	Grubbing
	Earthwork
1	Earthwork. 1,250 Bridges and culverts. 300
1	
,	Total\$2,170
1	Ties will cost, say 20 cents, although
ı	the average price paid for more than half
ı	a million ties used by the P. H. & N. W.
,	Ry., has been but little more than 10
ł	cents.
1	
	2,640 ties per mile at 20 c
1	per mile, at \$50 per ton 2,750.00
1	Figh plates 529 pairs weighing 8 lbs
ł	per pair, at 3 c. lb 127.08
	1,408 bolts, $\frac{1}{2}$ lb. each, at 4 c 28.16
1	per pair, at 3 c. lb
	less)
-	less)
	Ballasting, 35 c. yard 1,100 yards per
1	mile 385.00
	
5	Making per mile
Į	imum for siding, etc
	imum for siding, etc
ı	Total per mile\$4,346.72
-	We will perhaps arrive at a better re-
	sult for equipment by considering the
,	amount needed for 100 miles of road.
ı	Let us say,
,	
,	8 locomotives, from 14 to 20 tons @ \$8,000 each
I	\$8,000 each
1	6 second-class coaches @ \$2,300 each. 13,800
1	4 baggage and express cars @ \$1,700
1	each. 6,800 150 box cars @ \$325 48,750
	150 box cars @ \$325 48,750 10 stock cars @ \$350 3,500
	50 flat cars @ \$225
	Hand-cars 900
	Total for rolling stock\$167,000
	or \$1,670 per mile.
	Water stations at terminal stations, and
4	4 intermediate on the 100 miles will
,	cost \$700 each\$4,200 For station buildings we will say 12—6
	of the smaller size mentioned, which,
	with the platform and outbuildings
	complete will cost \$600 each 3,600
	Four, $20' \times 70'$ in size @ \$1,000 each 4,000
)	Two, 20'×100' in size @ \$1,300 2,600
•	Larger passenger and freight buildings at headquarters costing 15,000
	at headquarters costing
	Small engine-house at other end of line. 500
ı	Two turn-tables @ \$600 each 1,200
•	Machine shops and machinery 10,000
)	Car repair shops 6,000
9	Coach house
	Telegraph line 5,000

551.00 or \$551 per mile. Making a summary as Buildings.... 600.00 Fencing..... follows: Making a total per mile of......\$9,337.72 Right of way, road-bed, etc., per mile......\$2,170.00 Ties, iron, track-laying, ballasting, to which may be added engineering and contingent expenses, which will make in round numbers at least \$9,500 per mile. Rolling stock equipment......... 1,670.00

ON THE ANTISEPTIC TREATMENT OF TIMBER.

By S. B. BOULTON, Assoc. Inst. C. E.

From "The Engineer."

a paper by his late partner, Mr. H. P. Burt, Assoc. Inst. C. E., on the subject This appeared to prove that no chemical of timber preserving, which had been read at the Institution in 1853. Since that date the use of antiseptics for the treatment of timber had greatly increased. The process called creosoting, or the employment of the heavy oils of coal tar, had almost entirely displaced the other methods, whilst the manufactures connected with the residual products of gas making—from one of which residuals the Sir John Pringle, Sir Humphrey Davy, creosote oils were derived—had experienced an enormous development. The author's connection, during thirty-four years, with this group of industries enabled him to offer the results of some personal experience and research, which at by other investigators. An historical cessful of the processes. description of the antiseptic treatment of consisted in the employment of corrosive timber was preceded by a few notes on the sublimate, sulphate of copper, chloride preservation of wood and other perishable The ancients were well acmaterials. quainted with the manufacture and use of many kinds of oils, tars and bitumens, and frequently used them for the preparation of wood, with respect to which some notable instances were cited. The methods employed by the Egyptians in embalming their dead were dwelt upon at some length, and the author endeavored to elucidate some discrepancies in the descriptions of these processes, as

The author commenced by referring to to putrify when the antiseptic subpaper by his late partner, Mr. H. P. stances were removed by maceration. transformation had taken place, but that the long immunity from decay had been the result of the abiding presence of the antiseptic. The growth of theories upon the causes of putrefaction was traced down to the commencement of the present century, reference being made to the "Phlogiston," and other exploded theories; also to the opinions of Macbride, Thomas Wade, and others, and to their suggestions upon timber preserving. The progress of timber preserving during the railway era, and particularly between the years 1838 and 1853, was described, with especial reference to the he presented, together with those arrived competition between the four most suc-These four method pursued by the ancients for the of zinc, and heavy oil of coal tar, which had been patented in England respectively by Mr. J. H. Kyan, Mr. J. J. Lloyd Margary, Sir William Burnett, and Mr. The distinction John Bethell. pointed out between the real creosote—a product derived from the distillation of wood, but which had never been employed for injecting timber—and the so-called creosote which had been so successfully used for that purpose, the latter being a heavy oil produced from the distillation of gas tar. The theory that certain anrecorded by Herodotus and Diodorus tiseptics preserved timber by coagulating The researches of Petigrew the albumen, and by forming insoluble were alluded to, particularly his interest- combinations with the woody fiber, had ing experiment upon the heart of a been advanced on behalf of all the four mummy, which, after three thousand processes alluded to. But, in spite of some years' preservation, began immediately acknowledged success, the Kyanizing

Margaryizing, and Burnettizing systems opinion of Dr. Letheby to that effect was were not found to be so durable in their effects as creosoting. Indeed, the salts of metals were gradually washed out of timber exposed to the action of water. On the other hand, the success of the creosoting process became completely established. In order to show the process of manufacture of the creosote oils, a short description was given of the ordinary methods of tar distilling. Coal tar, a black, viscous substance, was a residual product of gas making. It was split up by a preliminary process of distillation into three groups of substances, namely: (1) Oils lighter than water, containing the naphthas, benzoles, toluols, timber. The result of these experiments and other bodies, from some of which the aniline dyes were manufactured. This series of oils had never been used tile portion of the crossote, and to those for timber preserving. (2) Oils heavier than water; the dead oils or creosote oils of the timber yards. These oils contained a great variety of different bodies, the properties of some of which were described, including carbolic acid, cresylic acid, naphthaline, anthracene, crysene, pyrone, quinolene, leucoline, acri- antiseptic for sanitary and surgical purdine, cryptidine, &c. (3) Pitch, the residuum of the distillation. oils varied in their characteristics in different districts, according to the nature of the coal used in the gas works, and to the varying temperatures at which the ations with other bodies, including albucoal was carbonized. The type of creosote called "London Oil," made from fore, readily evaporate from timber exthe tars derived from the coal of the posed to the heat of the sun, especially Newcastle district, was contrasted with in warm climates, and it would be washed the so-called "Country Oil," typical of out of timber in contact with water. and other coals. The former contains less of the carbolic and cresylic acids than the latter, but more of the semi-The history of the controore been preferred by many. The by the author to be a more practical ex-

recorded. On the other hand were cited the opinions and practice of the introducers of creosoting and of the earlier operators in that process, who used in preference the heavier types of creosote; and the early success of that creosote, both in England and in tropical countries, appeared to confirm their judgment. A number of experiments were then alluded to, stretching over a long series of years, and conducted by investigators in this and in other countries for the purpose of ascertaining which of the component portions of the creosoteoils were the most durable and efficient agents in preserving appeared to show that it was not to the tar acids, but to the heavier and least volabodies which solidified within the pores of the timber that the most durable results should be attributed. parent anomaly was explained by reference to numerous eminent authorities upon carbolic acid, who, whilst extolling its action as a most useful and powerful poses, were in general agreement as to The creosote its possessing the following characteristics: That it was exceedingly volatile at ordinary temperatures, that it was readily soluble in water, and that its combinmen, were not stable. It would, therethe product from the tar of the Midland The author's personal experience and experiments fully bore out the conclusion that the use of the heavier and least volatile portions of the creosote oils should solid substance, which solidified within be encouraged, and that from them the the pores of the timber, and more of the most durable results might be expected. antiseptics which did not volatilize Moreover, it was pointed out that recent except at exceedingly elevated tem-investigators had discovered in these heavy oils, bodies which, if perhaps less versy as to the respective merits of the potent, were more durable in their antitwo types of creosote oils was fully gone septic effects than carbolic acid. By ju-The carbolic and cresylic acids dicious selection and admixture, both had been recognized as potent antisep- London and country oils could be usetics; their presence appeared to arrest fully employed. Shale oil and bone oil, the action of all destructive germs, and however, and other oils lighter than the lighter and thinner country oils, water, should be excluded. The modern which contained a comparatively large germ theory was discussed in its relation percentage of these tar acids, had there to timber preserving, and was believed

planation of the action of antiseptics subject of the hygrometric condition of formation of insoluble compounds. With respect to all bodies which had been extensively used for timber preserving their durable results appeared to be in an inverse ratio to their volatility in the atmosphere and their solubility in water. The germ theory constituted a severe but salutary test in choosing antiseptics for the treatment of wood. In the author's opinion the substances preferred should be not only germicides, but germ excluleast soluble in water, least volatile in air, and most capable of becoming solid within the pores of the timber. A description followed of the various kinds of apparatus which had been in use during the present century for injecting timconcluded with some remarks upon the the topics alluded to in the paper.

upon wood than the older theories as to timber at the time of injection, failures the coagulation of albumen and the having repeatedly arisen owing to the timber being too wet at the time of creosoting. The author dwelt upon the importance of this subject, describing also his experience with various methods of getting rid of superfluous moisture artificially, and of a process which he had recently inaugurated, by which this result could be obtained in the creosoting cylinder itself, without injury to the tim-

The paper was illustrated by diaders, those being the best which were grams showing the most important products derived from coal, and the apparatus for coal tar distillation and timber preserving; also by tables, giving the properties of coal-tar products and other substances, of timber-preserving specifications, and of more than one hundred ber with antiseptic liquids. The paper references to various authorities upon

THE MANUFACTURE OF CRUCIBLE CAST STEEL.

BY HENRY SEEBOHM.

Transactions of Iron and Steel Institute.

The old-fashioned method of converting bar iron into steel, and afterwards melting it in clay pots to form ingots of cast steel, which are reheated and rolled or hammered to the size and shape rethat I should not have ventured to bring the subject before the notice of the members of the Iron and Steel Institute had I not been requested to do so by the council of the society. It was suggested that, inasmuch j

that the Patent Laws are so bad that it is more profitable to keep secret a mechanical improvement than to patent it. Sheffield inventors have learnt by bitter experience that secrecy is the only proquired, has been so frequently described tection for improvements; and if they think that they have found a goose that is going to lay golden eggs they lock and double lock the fowl house door. It is said that there is no Act of Parliament through which you cannot drive a coach-and-four, and I am afraid that the as the Journal of the institute did not Patent Laws are no exception to the contain a paper on this subject, the occa- rule, if you only have sufficient money to sion of the annual meeting of the mem- buy a strong enough team. I may prebers being held in the town of Sheffield, mise that I have nothing new to bring the headquarters of the crucible cast forward. No Sheffield firm has yet sucsteel trade, would present an appropriate ceeded in discovering the philosopher's opportunity for collecting the facts constone. We all have our little secrets, nected with such an important branch of which we jealously guard (and they have industry. These facts may perhaps be no greater scientific value than the all the more interesting now that Shef-secrets of the Masonic fraternity), but in field has somewhat ungraciously failed spite of the important and valuable disto respond to the wishes of the institute; coveries which have been perfected durnot in the least degree from want of hos-ling the last quarter of a century in the pitality, but from a deeply-seated belief methods of producing cast steel, the oldfashioned crucible steel manufacturers of Sheffield still hold their own. They still convert bar iron into blister steel, and melt blister steel into cast steel, and some of them have not been altogether unsuccessful in transmuting cast steel into

gold.

The accumulated experience of a century has convinced the manufacturers of crucible cast steel that the finest qualities can only be made from bar steel which has been converted from iron manufactured from Dannemora ore. This iron is expensive; its average cost for the last forty years has been at least £25 a ton; the process of converting it into steel is slow and costly; the process of melting in small crucibles is extravagant both in labor and in fuel, and consequently the best qualities of crucible cast steel can only be sold at a high price. So-called best crucible cast steel is sold at low prices by unscrupulous manufacturers, and bought by credulous consumers, but though it is quite possible for highpriced steel to be bad, it is absolutely impossible that low-priced steel can be good. The finest quality of steel cannot be made of cheap material or by a cheap process. Every year the attempt is made, ever made a better try than Sir Henry Bessemer, but his failure was as complete as that of his predecessors. He attempted to produce an article at £6 a ton to compete with one at £60 a ton, and failed absolutely. It is true that his steel is a success, perhaps the most brilliant success of the century. I am not quite sure that he himself believes in his In his lecture before the Cutlers' Company of London, in 1880, he chaffed the steel manufacturers of Sheffield on their antiquated attachment to the rule of thumb, and twitted them with the assertion that the high price of crucible cast steel arose from a combination of trade interest on their part and of prejudice on the part of their customers. Sir Henry Bessemer may have half ruined the wrought-iron trade, and revolutionhis great discoveries. price of horses would permanently fall, gether. Of every fact there must be

but exactly the contrary took place. Similar fears were entertained that the demand for crucible cast steel would seriously decline when Bessemer and Siemens steel came into the market. not been the case. The commoner qualities of crucible cast steel have been, to a large extent superseded by Bessemer and Siemens steel, but the enormous quantities made by the latter processes have required for their manipulation, directly or indirectly, such a large quantity of the better qualities of crucible cast steel, that the total amount of the latter now produced in various parts of the world is probably double that which was required before the birth of its rivals.

Chemical analysis plays a very important part in the manufacture of iron, Bessemer and Siemens steel, and even of the comparatively small quantity of crucible cast steel which is still used for purposes in connection with which it is not required to be hardened and tempered. It is possible to judge very accurately of the quality of those metals from their chemical analysis, almost as much so as from the results of mechanical tests, such as the breaking strain and the contraction of the area of fracture. and every year it signally fails. No one But in what we may call, for want of a better name, the legitimate cast steel trade, chemical analysis, though it tells us a great deal, does not tell us everything. The analysis of steel shows the amount of other ingredients which it contains besides the nine-tenths or more of iron which forms its basis. amount of carbon, silicon, manganese, sulphur, phosphorus, copper, &c., may be ascertained with tolerable accuracy, and the information thus obtained is often of the utmost importance; but it is quite possible to make a comparatively lowpriced steel which shall show precisely the same chemical analysis as the best crucible cast steel; nevertheless it is found by practical experience to be inferior in quality. That this is a fact has been proved over and over again beyond all possibility of doubt. It is a sufficient ized the pig-iron trade, but the crucible reason why Sheffield manufacturers have cast steel trade holds its own in spite of been willing to pay such a high price for When railways Dannemora iron for so many years; but were first introduced, and wagons and it is not a sufficient reason why so many coaches were to a large extent driven off Sheffield manufacturers should ignore the road many people thought that the the results of chemical analysis altosome explanation, though we may, for the esses than it is by that made by the oldpresent, at least, be ignorant of it. To say, with the Sheffield devotees of the rule of thumb, that the one steel possesses "body," and that the other does not, explains nothing, but merely adds to the synonomy of the subject by altering the nomenclature. If the metallurgical chemists could once convince themselves that this difference in quality is a fact, they would probably soon be able to give us an explanation. We already know much of the chemistry of steel, and what remains to be learnt is as certain to be some day discovered as the fact that Newton discovered the laws of gravita-Mathematicians may never discover how to square a circle, mechanics will never discover a perpetual motion, nor will chemists ever discover the transmutation of metals; but the discovery of the chemical explanation of "body" is only a question of time. By way of stimulating enquiry I venture to suggest two possible causes of body which may be worth consideration as a tentative hypothesis of its nature. The best razor-steel contains one and a half per cent. of after it has become perfectly fluid as carbon. It must be melted from evenly possible, and as hot as the tensile converted steel. It will not do to mix strength of the pot will allow. In makhard and soft steel together, or to melt ing the higher qualities of crucible cast it from pig "let down" with iron, though steel (where the percentage of phosin either case the exact one and a-half per cent, of carbon may be the result. Steel made by the latter processes will not very strange results; the molten steel possess the requisite amount of body; consequently, the cutting edge of the ture of the ingot when cold would show razor will not stand. It must be melted a series of bubbles like a sponge, and its from steel converted from iron made specific gravity would scarcely exceed from ore containing manganese. It will that of wood. Some of these bubbles or not do to add the manganese in the form honey-combs would weld up when the of spiegeleisen or ferro manganese. Carbon and manganese exist in combination greater number would be coated with an with iron not chemically combined in oxide, which would make a weld imposcertain definite proportions, but as al-sible, and the bar, if it was not burnt up loys, as mechanical mixtures in any in the fire, would be so full of the imperproportion. exists in combination with iron in two "roaks" as to be perfectly useless. forms, either as combined carbon obviate this disastrous result it is necesor free carbon; is it not possible sary to boil the steel for nearly half an that manganese may also exist in two hour after it has become fluid, and then neous in steel made by the cheap procquality of the steel the more "killing" it

fashioned method? It has been stated that the finest qualities of steel when hardened show a more perfect regularity in their crystallization when examined under a microscope than commoner qualities, and I venture to suggest that a possible explanation of "body" in steel may be absence of injurious ingredients, combined with the perfectly homogeneous presence of the advantageous ingredients. Hardened steel is crystallized steel; and perfect regularity of crystallization in steel which is required to be ground to a fine cutting edge may be a necessity which can only be secured by the slow and expensive old-fashioned method.

The principal reason why Bessemer and Siemens steel have failed so completely to supersede crucible cast steel for purposes where the better qualities are required, is that they cannot be made sound without the addition of silicon or manganese. In melting common steel (containing, for example, from 0.15 to 0.05 per cent. of phosphorus), the steel phorus ranges from 0.01 to 0.001) a similar mode of treatment would produce would boil over in the mould, the fracingot came to be forged, but by far the We know that carbon fections technically called "seams' forms, and though the razor steel must to allow it to cool down to a certain temhave been boiled in the pot for half perature before it is poured into the an hour after it was melted, to kill it and mould. This process is called, in the make the ingot pipe, is it not possible language of the votaries of the rule of that the mechanical mixture of the car- thumb, "killing" the steel, and it is an bon and the manganese is less homoge- axiom amongst them that the higher the

of crucible cast steel melting that its which it has presumably had an opporto bear upon it. There is an old proverb in Sheffield, usually expressed in the case if we suppose that the scrap (which crucible his Satanic Majesty will come or silicon helps largely to kill the steel out of the crucible. this is by no means the case. crucible, you cannot convert bad steel inyou may put the most angelically pure phorus, the occluded gas is expelled at a steel into the pot, you may, by bad man-agement, by not "killing" it properly, iron. Before describing the process of pervert it into satanically bad ingots. making crucible cast steel, it may be use-Now, this killing of the steel is precisely ful to devote a few words to the nomenwhat cannot be done in the Bessemer or clature of iron and steel. This is almost Siemens processes without the addition as much a vexed question as that of zooof such a large amount of manganese or logical nomenclature, and might form the silicon that the steel becomes brittle subject of a code of laws, which would when hardened. I do not know whether chemists are agreed on an explanation of the necessity for "killing" high-class steel. When iron is made into steel in a converting furnace, it is assumed that the oxygen in the air in the converting pot unites with the charcoal, and is soon made into carbonic oxide, which is occluded by the white-hot iron, and forced tinct, and each of which we subdivide by it to part with as much carbon as is sufficient to reduce it to carbonic acid. that neither our generic nor specific It has been ascertained that metals names are very scientific. have the power of absorbing or occluding many times their own bulk of gas, and possibly the carbonic oxide, when it has parted with the amount of carbon necessary to reduce it to carbonic acid, is not then expelled from the iron, but may remain in an occluded state, and requires to be expelled in the melting pot by boiling. Be this as it may, it is a fact that if it be required to make blister steel harder than about 1.4 per cent. of carbon, it is necessary to convert it twice over, possibly in order that in the interval it may part with some of its occluded carbonic acid, so as to make room for a further occlusion of carbonic oxide.

Another fact which may throw some long. light upon this question is, that blister steel melted directly after being drawn from the converting furnace requires puddling is stopped when rather more more "killing" than that which has been than half of the carbon has been re-

takes. It is in this part of the process exposed to the air for some time, during special virtue consists, and the cost and tunity of parting with some of its ocquality of the cast steel produced depend cluded gas. The addition of a portion of in a large degree upon the skill brought scrap steel materially assists the process of "killing," as would naturally be the terse vernacular of the county, but which has been melted before) has parted with may be refined into the expression that its occluded gas in the first melting. if you put his Satanic Majesty into the The fact that the presence of manganese The converse of may possibly be accounted for on the Though theory that the carbonic acid unites with you may convert iron into steel in the the manganese or silicon, and becomes a solid, or it may be that in an alloy of iron to good steel in the crucible; but though with either manganese silicon or phosprobably be as complete a failure as those issued under the auspices of the British Association for the Advancement of Science, which have made confusion in the scientific names of birds and beasts worse confounded. In Sheffield we attempt to discriminate between iron and steel, which we regard as generally disspecifically, though it must be admitted

> Pig iron is melted direct from the ore in a blast furnace, and contains from 3 to 5 per cent. of carbon. When remelted it is called "cast iron," or "metal."

> Spiegel iron is precisely the same, but contains in addition from 5 to 15 per cent.

of manganese.

Bar iron, often called wrought iron, is pig iron which has been smelted and deprived of nearly all its carbon, either in a puddling furnace, or by the Walloon, Lancashire, or other analogous process; the spongy mass or ball of iron is usually hammered or rolled into a bar, which, for the Sheffield trade, is generally 3 inches wide 5 inch thick, and from 6 to 12 feet

Puddled steel is precisely the same as "bar iron," except that the process of moved from the pig iron. There is, consequently, no hard and fast line between bar iron and puddled steel, the one intergrading to the other by imperceptible degrees. Although there are an infinite number of intermediate stages between the softest bar iron and the hardest puddled steel, and although it is impossible to state the exact percentage of carbon which marks the dividing line between one and the other, it is usual to call all puddled bars which cannot be hardened in water, bar iron, and all those which can, puddled steel. This dividing line falls somewhere near a mixture containing ahalf per cent. carbon, and although it looks very vague and unscientific to use two terms which thus intergrade, no confusion of any kind, or misunderstanding, has ever been known to arise from their

Blister steel is bar iron which has been converted into steel in a converting furnace, and varies in the amount of carbon which it contains from ½ to ½ per cent. There are of course, an infinite number of degrees of carbonization between "hard heats" and "mild heats," but for the convenience of the trade six of them have been selected, and have received names as follows;

No. 1. Spring heat..... $\frac{1}{2}$ per cent. of carbon. No. 2. Country heat.... $\frac{5}{8}$ " " No. 3. Single-shear heat. $\frac{3}{4}$ " " No. 4. D'ble-shear heat. $\frac{1}{4}$ " " No. 5. Steel-thr'gh heat. $1\frac{1}{4}$ " " No. 6. Melting heat.... $1\frac{1}{2}$ " "

Bar steel is blister steel which has been tilted or rolled down to the size required.

Single-shear steel is produced by welding half a dozen bars of blister steel together. Only those bars are chosen in which the process of conversion has been so far carried on that the outside of the bar is steel, and the center of the bar iron. When these are welded together, and tilted or rolled down to a small dimension, the result produced is a metenial mixture of iron and steel, a material which combines great tenacity with the capability of carrying a moderately hard cutting edge, and is much employed for certain kinds of knives.

Double-shear steel is produced by drawing down single shear to suitable sized bars and rewelding two of them to-

gether, so that the mixture of iron and

steel may be more perfect.

Cast steel is steel that has been melted in a "pot" (called a crucible in the encyclopædias), and poured into a mould (called a "form" in the learned books), thus becoming an "ingot," which is afterwards hammered or rolled to the size required. It may be made of various "tempers," varying in the percentage of carbon which they contain from threequarters or less to one and a-half or more. The different tempers may be arrived at in various ways. For the great majority of purposes there can be no doubt that the best way is to put into the melting pot broken pieces of blister steel converted exactly to the temper required; and the more evenly the steel is converted, and the more carefully all bars which are harder or softer than the temper required, or which are "flushed" or "aired," are rejected, the better. Blister steel, when carefully "taken up" or selected, will produce a cast steel which combines the greatest amount of hardness with the maximum amount of elasticity when hardened. It may, however, happen that for certain purposes "soundness" in the bar, the result of absence of honey-combs in the ingot, may be the most important quality required in the steel; for others, the property of welding most perfectly may be the sine qua non; or the great evil to be avoided may be the tendency to water-crack in hardening; or the steel may be used for some purpose where it does not require to be hardened, and the object to be secured is the combination of the greatest amount of hardness and toughness when unhardened. In all cases the mode of manufacture must be adapted to the objects which it is most important to secure. In addition to the mode of operations already mentioned, there are two other ways in which the same percentage of carbon may be secured. You may either put cut bar iron into the pot, and "fetch it up" to the required temper with charcoal, or you may put broken pig iron into the pot, and "let it down" to the required temper with cut bar iron. fourth modus operandi, which, for most purposes is the best of all, might be enumerated, namely, the selection of blister steel slightly harder than the temper required, so as to admit of being slightly let down to the exact temper by the ad- the charcoal inside. dition of a small quantity of somewhat milder cast steel scrap.

Bessemer steel or Siemens steel do not require definition, nor do they come

within the scope of this paper.

generally called in the encyclopædias, the process of cementing iron into steel, is carried on in a converting furnace. This furnace consists of two stone troughs, technically called "converting pots," each of them about 4 feet wide, 4 feet deep, and 12 feet long, and placed side by side with a fire underneath them, the flues of which conduct the heat all around each which have arisen on the surface during pot. These troughs or pots are built up the process of conversion. Some of the of slabs of a peculiar kind of firestone, charcoal has been consumed during the obtained in the neighborhood of Shef- week at which it was white hot, but a field, and possessing the property of not considerable portion of it remains, and cracking if heated slowly to a high heat is taken out of the furnaces as black and allowed to cool slowly. are united together with a mortar made in the composition of the bars has of ground fireclay. Over the two pots is built a vault of firebrick, and the pure iron, or nearly so, containing, whole is enclosed in a dome of red brick, to prevent as much as possible the heat from escaping. At the bottom of each pot is placed a layer of charcoal, broken up into small pieces, from a quarter to half an inch square. On this a layer of pot is filled with alternate layers of they have been subjected. They are now closed with a thick cover of "wheelswarf," a silicious species of mud which the hammer. The converting furnaces accumulates at the troughs of the Sheffield grinding wheels, and is, of course, the material of the grindstone, worn away in the process of grinding, and mixed with the finest steel dust which has been ground away, a substance which will resist long exposure to great heat, and renders the top of the pot practically air tight. In order to test the progress of conversion, and to ascertain the precise moment when the fire should be allowed to go out, two or three bars of iron are allowed to protrude through a hole in one of the pots made for the tightly packed in white ashes where they said to be "aired," and even when very pot, so that no air may find its way to in consequence of their having almost lost

The converting pots, full of alternate layers of iron and charcoal, and for all practical purposes hermetically sealed, are gradually raised to nearly a white heat, and kept at about that temperature for a week or more, The process of converting, or, as it is according to the amount of carbonization required. Another week is occupied in the process of cooling, which must be done slowly, in order to prevent the pots from cracking, after which the cover is broken up and removed, and the bars, which went into the furnace bars of iron, are taken out of it bars of "blister steel," so called from the bubbles or blisters The slabs as it went in. A chemical change perhaps, one-quarter per cent. of carbon, or less, were fibrous in their structure, and would bend double without breaking. After the process of conversion they have become a carburet or carbide of iron or steel, containing from half to one and abars of iron is placed, which is covered half per cent of carbon, according to the with charcoal; another row of bars length of time they have been in the of iron follows, and so on until the furnace and the degree of heat to which charcoal and iron; it is then carefully more or less crystalline in their structure, and can be broken by a slight blow of in use in Sheffield vary in size, some holding as much as thirty tons of iron, and others not more than fifteen tons. iron gains slightly in weight by being converted into steel. The process occupies about three weeks, and a pair of pots may be used from twenty to forty times before they are worn out and have to be replaced by new ones.

As in every other process connected with the manufacture of steel, in the process of conversion it has to run the gauntlet of many perils. Sometimes the pots crack, air is admitted to the furnace, purpose. These bars, technically called the charcoal is burnt, and in bad cases "tap bars," are drawn and inspected at even the iron is oxidized. Bars which have or near the close of the process, and are thus missed conversion are technically pass through the end of the converting slightly affected may be easily discovered, the tendency to become rusty. If the furnace be raised to too high a heat the surface of the bars will melt, and when they are drawn it will appear "glazed." There are even instances handed down by tradition in Sheffield of unskillful convertors, who had heated the furnace under their care to such a degree that the whole mass of iron and charcoal had become fused together, and the end of the furnace had to be taken out to remove the contents. During the process of conversion the outside of the bar of iron is turned into steel the first, and in a spring heat the center of the bar remains iron, though when the bar is broken the crystals of iron have lost their brilliancy; in technical language, the bar is said to be full of "sap," though the sap is "killed," and no longer looks "raw" or "stares." In a country heat the sap is still more killed, and the crystals of steel on the edges have become more distinct. In a single-shear heat the fracture shows more steel on the outside, and less iron in the center, until, in a doubleshear heat, the fracture shows about equal proportions of iron and steel. It is important that the transition from one to the other should be as gradual as pos-When the line of demarkation is violent or sudden, the process of conversion has been carried on too rapidly, and bars of blister steel so converted are said to be "flushed." In a steel through heat, as its name implies, all trace of iron in the fracture has been lost sight of, times, containing severally about 50, 44 but the crystals of steel are small. A short time longer in the furnace will make the steel a melting heat; the crystals will be large, and in exceptional cases their facets will reach across the bar. The melting furnace consists of a row of oval melting holes, large enough to contain two melting pots, one in front of the other, and deep enough to allow of sufficient coke to cover the lids. From each melting hole a flue leads, in oldfashioned furnaces, into a flat stack, each hole having a separate flue in the stack, but many furnaces are now made with short flues from each hole leading into a main flue which ends in a single square chimney. The application of gas to the melting hole, through an iron funnel melting of steel has been successful, but called a charger. The lid is carefully for the highest qualities coke is princi- adjusted, and the melting hole filled with pally used, as the control which the coke. The degree of heat to which

pot, which sometimes requires "keeping back" and sometimes "hurrying on," is supposed to be more absolute. There can be little doubt, however, that the adoption of gas melting furnaces is only a question of time. The furnace floor is on a level with the top of the melting holes; and the grate bars, as well as a flue leading into the chimney, by which the draft may be controlled, are accessible from the cellar. The pots in which the steel is melted are generally made in a room adjoining the melting furnace. They are composed of a mixture of Burton and Stannington clay, to which is sometimes added a proportion of Stour-bridge clay, and, if the pots are required to stand a great heat, of China clay from Devonshire. A small quantity of ground coke, as well as of old pots ground, is also added. Great care is taken that the clay be absolutely disintegrated and perfectly mixed together. This is accomplished by treading it in a trough, the potmaker and his assistant kneading it with their bare feet. The pots are moulded in an iron "flask" by means of a wooden "plug," and are slowly dried at the back of the stack, and the night before they are used gradually heated to a dull red heat, a process called annealing. Pot-making is a very important part of the manufacture of best cast steel. It is absolutely impossible to make good cast steel if the pots are defective. Each pot lasts a single day, and is used three and 38 lbs. of steel each round. The object of lessening the weight of each successive charge is to bring the surface of the molten metal to a different place in the pot, because the "flux," or scum, which accumulates on the surface has a chemical action on the silica of the pot, which is consequently decomposed for some depth just at that point, and the pot is reduced in thickness.

The bar steel is first carefully selected of the exact temper required, all flushed or aired bars are rejected, and after it has been broken up into small pieces and carefully weighed, it is conveyed to the pot, which has already been placed in the melter has over the temperature of each the furnace is allowed to go is carefully regulated by the "puller-out," who is technically said to "work" the holes, and who has perfect control over them by means of the two flues, into either of which he can insert a firebrick if required; a brick in the melting hole flue lessens the heat by lessening the draft; one in the cellar flue increases the heat by increasing the draft. The head melter periodically inspects the pots, and gives the final instructions to the pullerout, and decides the precise moment when the steel is dead melted, and the holes sufficiently burnt down to allow of its being "teemed" or poured into the mould with a fair chance of producing a sound ingot. When the "puller-out" has put on his "clothes," by which is meant a series of sacking wraps which envelop the arms and legs, and are soaked with water to protect him from the heat, he raises the pot with a pair of "pullingout tongs," and lifts it from the hole to the floor of the furnace. The lid is instantly taken off with a pair of lid tongs, and the scum or flux is removed by a skimmer from the surface of the molten steel, which is then poured into a castiron mould formed of two halves tightly ringed and wedged together. The interior of the mould has been previously "reeked" or covered with a coat of coaltar soot, to prevent the ingot from adhering to it. The melting of the higher qualities of steel is a process requiring the greatest skill, and one of the principal reasons why the trade has become to such a remarkable extent localized in Sheffield, is the importance to this branch of the trade of being able to select from a large class of more or less experienced workmen, the few exceptional men in whom sound judgment, technical skill, and steady habits are combined. The chances of accident in the melting of steel are many and various. Not only badly made pots, but badly annealed or badly worked pots, are sure to "run," and the steel to be deposited amongst the ashes, where it imbibes so much sulphur as to be practically of no value. Should a piece of coke accidentally find its way into the pot, the ingot will show a bright sparkling fracture—technically speaking it will be said to "stare"—and under the hammer will prove "hot short,"

fiery and produce a honeycombed ingot, and the same result will follow if it be too hot when it is poured. If it remain too long in the fire it will teem "dead," "the fracture of the ingot will look scorched," and though exceptionally sound, it will be brittle if hard, and wanting in tensile strength if mild. If the molten steel be chilled before it is poured into the mould, which may be detected by the stream skimming over as it is teemed, the fracture of the ingot will appear dull in color, and full of small holes or honeycombs.

All ingots having a proportion of 1 per cent. or more of carbon, if properly melted with pipe, that is to say, the steel in the center of the ingot will settle down as it cools, leaving a hollow space in the middle at the top of the ingot to the depth of from 3 to 5 inches. When the ingot has become cold it must be topped, that is to say, the hollow part must be broken off, until the ingot shows a sound fracture, and before this fracture has had time to rust, the ingots must be carefully examined; the ingots which are not properly melted must be rejected, and the exact percentage of carbon which each ingot contains must be marked upon An experienced eye can judge of the percentage of carbon contained in an ingot to a wonderful nicety by the appearance of the fracture. Between 1 per cent. of carbon and 11/2 per cent. every tenth per cent. is well marked, and an experienced hand will detect a difference between, for example, 1.3 and 1.35 per cent. In order to reduce the ingot of cast steel to the size and shape required by the consumer, it must be reheated, and, when hot enough, hammered or rolled to the dimensions ordered. Great care must be exercised in this process not to burn or overheat the steel: and, to prevent this, the half "cogged" bar must be continually turned round in the fire, and ground fireclay or sand and borax sprinkled upon it. In many cases it is necessary to give the surface of the bar, after it has been once drawn down under the hammer, a welding or "wash" heat, to close the small honeycombs which are scattered here and there on the surface of the ingot. It is a matter of great importance, especially with large ingots, and crumble to pieces. If the steel be that they should not be hammered until not long enough in the fire, it will teem they are thoroughly heated or "soaked" through, and it is of equal importance to all ingots that they should not lie too long "soaking" in the fire, especially in a dry fire, that is, one without blaze. The effect of hammering steel is to make it crystallize in very small crystals, a result which greatly improves its quality, but at the same time exposes it to the risk of various accidents in the process. The forging, tilting, and rolling of cast steel all require very experienced workmen, and a considerable outlay of expensive It is seldom that a workmachinery. man attains exceptional skill in many de partments, and great loss is sustained by too often changing faces or rolls, so that these processes cannot be satisfactorily or cheaply carried on upon a small scale, and this is one of the chief reasons why the crucible cast steel trade has to such a large extent become localized in a

single town. It might be supposed that when the best quality of iron had been selected, and the greatest care used in all the processes of manufacture—the converting, the melting, and the forging—the result must of necessity be good steel, and the troubles of the steel manufacturer would be over. But this is not the case by any means. So far from being over, the greatest difficulty has yet to be faced. The result may be good steel, but good steel only for certain purposes. There was a time, in the golden age of steel manufacturing, when steel was steel; and if it did not answer the purpose for which it was required, it was taken for granted that the fault lay with the workman. In some cases the manufacturer altered the percentage of carbon; but the "temper" of the steel was kept a profound secret from the consumer in most cases, no doubt, because the manufacturer had very vague ideas on the subject himself. Chemical analysis was unknown in the trade; the despotic sway of the rule of thumb reigned su-Now it is customary for the manufacturer to take the customer into his confidence, and not only to inform him of the percentage of carbon which the steel contains, but also to give him the benefit of his opinion as to the purposes for which it is or is not suitable. Formerly, if the consumer discovered that chisel steel contained less carbon than tool steel, he owed his discovery en-

tirely to his own wit. There can be no doubt that for many purposes a considerable latitude may be permitted, if the steel has the good fortune to fall into the hands of a clever workman who understands how to "lumor" it, but next to quality—by which is meant percentage of phosphorus, sulphur, &c., combined with some other obscure points of crystallization—the most important thing is temper, or percentage of carbon. For some purposes, indeed, temper is of more importance than quality. Nothing is more common than for steel to be rejected as bad in quality, because it has been used for a purpose for which the temper was unsuitable. We may divide consumers of steel into three classes. First, those who use their own judgment of what percentage of carbon they require, and instruct the manufacturer to send them steel of a specified temper; second, those who leave the selection of the temper to the judgment of the manufacturer, and instruct him to send them steel for a specified purpose; and third, those who simply order steel of a specified size, leaving the manufacturer to guess for what purpose it is required. Fortunately, the size and shape generally furnish some clue to the purpose for which it is likely to be used. For example, oval steel is almost sure to be used for chisels, and small squares for turning tools, but $1\frac{1}{4}$ square may be used for a turning tool or a cold sett, or $1\frac{1}{4}$ round for a drill or a boiler cup, and the manufacturer has to puzzle his brain to discover whether the chances are in favor of its being used in the lathe room or in the blacksmith's shop. It cannot too often be reiterated of how much importance it is, when ordering steel, to state the purpose for which it is going to be used. Of course the number of tempers of steel is infinite, but the following is a list of the most useful:

Razor temper ($1\frac{1}{2}$ per cent. carbon).— This steel is so easily burnt by being over-heated that it can only be placed in the hands of a very skillful workman. When properly heated, it will do twice the work of ordinary tool steel for turning chilled rolls, &c.

Sawfile temper (1\frac{2}{5} per cent. carbon).— This steel requires careful treatment; and although it will stand more fire than razor-steel, should not be heated above a

cherry-red.

Tool temper (1½ per cent, carbon.)-The most useful temper for turning tools, drills, and planing-machine tools in the hands of ordinary workmen. It is possible to weld cast steel of this temper, but only with the greatest care and

Spindle temper ($1\frac{1}{8}$ per cent. carbon).— A very useful temper for circular cutters, very large turning tools, taps, screwing dies, &c. This temper requires consider-

able care in welding.

Chisel temper (1 per cent. carbon).—An extremely useful temper, combining as it does great toughness in the unhardened state, with the capacity of hardening at a low heat. It is consequently well adapted for tools when the unhardened part is required to stand the blow of a hammer without snipping, but where a hard cutting edge is required, such as cold chisels, hot setts, &c.

Sett temper ($\frac{7}{8}$ per cent. carbon).—This temper is adapted for tools where the chief punishment is on the unhardened part, such as cold setts, which have to stand the blows of a very heavy ham-

Die temper ($\frac{3}{4}$ per cent. carbon).—The most suitable temper for tools where the surface only is required to be hard, and where the capacity to withstand great pressure is of importance, such as stamping or pressing dies, boiler cups, &c. Both the last two tempers may be easily welded by a mechanic accustomed to weld cast steel.

It is a somewhat remarkable fact that although steel is intermediate in chemical composition between wrought iron and cast iron, containing more carbon than the one and less than the other, its properties are quite different from either of them. It may be made to resemble either of them alternately, but it is principally used in a third condition, in its capacity to assume which the great value of steel consists. Annealed steel has nearly all the properties of lead, being very soft and malleable. Hardened steel has nearly all the properties of glass, being very hard and brittle. ing hard but at the same time elastic. The chemical change which takes place raised above a certain point, the steel beduring these processes has not yet been comes what is technically called "burnt." Vol. XXXI.—No. 6—35

discovered. We might evolve a very pretty theory to account for it, by assuming that in the process of annealing some of the combined carbon was liberated, and existed in the steel in the form of free or uncombined carbon; but such a theory only explains part of the facts, and is not, I am afraid, borne out by the results of chemical analysis, so that we must fall back upon the mysterious and unknown laws of crystalization. effect cannot be due simply to the increased density of the hardened steel caused by the contraction of the steel by sudden cooling. It is a remarkable fact that the specific gravity of hardened steel is less than that of unhardened steel. Steel, of course, expands with heat, and when it is allowed to cool slowly regains its original size; but if it be cooled suddenly, the only known way in which it can be hardened, although it contracts very much, it does not quite reach the small size of the unhardened state. However complicated the details of the manufacture of cast steel may be the complications involved in its subsequent use are still greater. It would be impossible to lay down exact rules for each of the thousand and one tools in which steel is The treatment of each tool in used. each process which it undergoes is an art that can only be learnt by practice, and can no more be taught in a book than the arts of skating, riding, or swimming. The utmost that can be done is to lay down certain general rules, which may explain to some extent, if they fail to teach, the most important details of manipulation. All steel may be regarded as involving a question of compromise. Each tool requires a certain degree of hardness; the problem is how to secure the maximum amount of toughness that is compatible with it. To secure this, the first step that must be taken in bringing the steel into the shape required is to heat the steel as little as may be before it is forged, and in the process of forging to hammer it as much as possible. The worst fault that can be committed is to heat the steel more than is necessary. When steel is heated it becomes coarse-Tempered steel has grained; its silky texture is lost, and can most of the properties of whalebone, be-only be restored by hammering or sudden cooling. If the temperature be

and the amount of hammering which it would require to restore its fine grain would reduce it to a size too small for the required tool, and the steel must be confire is also the primary cause of cracking in the water. One of the principal reasons why a high quality of steel is required for certain purposes is, that it will reheated a greater number of times, than must on no account be overheated. cut into them. Before this can be sucprocess has to be gone through. cutting of teeth into it impossible or difficult, and it must consequently be annealed. This process consists in reheating the steel as carefully as before, and afterwards allowing it to cool as slowly as possible. Many tools are only required to be hardened on a small part of their surface, and it is important that the unhardened parts should possess the maximum amount of toughness, the minimum amount of brittleness that can be attained. The process of annealing, or slow-cooling, leaves the steel coarsegrained, gives it its maximum of ductility, and causes it, in fact, to approach in its properties those of lead.

The last process in the manufacture of articles made of steel, where the invaluable property which distinguishes steel from wrought iron or cast metal is revealed, is the double process of hardening and tempering, by which we suddenly change the steel from lead into glass, and afterwards gently change the glass into whalebone. In these as in all other processes which steel has to undergo, it has again to run the gauntlet of fire. It does so, however, at much greater risk than heretofore. The forging of the parts, it is often wise to drill holes in the

shape to which it was destined; and any injury which may be done to it by overheating is irrevocable, and can no longer be cured or mitigated by the hammer. It demned as spoilt. Overheating in the is necessary, therefore, to double and redouble the care bestowed upon the heating of the steel, lest the temperature be raised beyond the point necessary to secure the required hardness. The part of suffer less injury by being heated to a the steel required to be hardened must greater degree, or by being heated and be heated through and heated evenly, but inferior qualities of steel. In heating steel tool must be finished at one blow, the the happy medium must be attained be blow caused by the sudden contraction tween heating it too much or too little, and of the steel produced by its sudden coolbetween letting it lie too long "soaking" in ing in the water, and if this blow be not the fire and not "soaking" it through sufficient to give to the steel a fine grain Both the degree of temperature and the and a silky texture, if after the blow is duration of the heat must be carefully given the fracture (were the tool broken watched. Some tools, such as circular in the hardened part) would show a cutters, files, &c., after they are forged coarse grain and dull color instead of a into the shape required, must have teeth fine grain and glossy luster, the tool is spoiled, the labor bestowed upon it is cessfully accomplished a preliminary thrown away, and it must be consigned The to the limbo of "wasters." The special process of hammering or forging the dangers to be avoided in hardening each steel into the shape required has hard- kind of tool must be learned by experiened it to such an extent as to make the ence. Some tools will warp, or "skeller," as we say in Yorkshire, if they are not plunged into the water in a certain way. Tools of one shape must cut the water like a knife; those of another shape Some tools must stab it like a dagger. must be hardened in a saturated solution of salt, the older the better; whilst others are best hardened under a stream of running water. Most tools have a tendency to water-crack if taken out of the water before they are absolutely cold. Where the edge of a tool only is hardened care should be taken to move it up and down in the water, so as continually to change the water level lest the tool should crack at the water level. Steel contracts in hardening, and contracts differently where it is cooled suddenly from the places where it is cooled slowly. If the hardened part joins the unhardened part too suddenly, the steel at the junction will be in a dangerous condition of tension, which predisposes it to crack, and it is wise to lessen the amount of tension by distributing it over as great an area as possible. In some tools, where the shape necessitates a great difference in the rapidity of the cooling of the various tool is finished; it has taken the final thicker parts, where they will not interfere with the use of the tool—holes which are made neither for use nor ornament, but solely with a view of equalizing the rapidity of the cooling of the various parts, so as to distribute the area of tension, and thus lessen the risk of cracking inaccuracy." in hardening. So many causes may produce water-cracks, that it is often difficult to point out the precise cause in given case. The most common cause is the overheating of the steel in one or other of the various processes through which it has to pass. A second cause may be found in the over-melting or too long boiling of the steel, causing it to part with too much of its occluded carbonic acid, a fault which may be attributed to the anxiety of the manufacturer to escape honeycombs in the ingot: A third cause may sometimes be discovered in the addition of too much manganese, added with the same motive. fourth cause may, curiously enough, prove to be a deficiency of carbon, one of the most common causes of water-cracking in files; whilst in some cases too much carbon will produce the same effect. A fifth cause may be one which, as a steel manufacturer, I ought to mention in a whisper—the presence of phosphorus in the steel; but, after all, this may not be the fault of a too greedy manufacturer, who wants to make too much profit; it may possibly be the fault of a too stingy consumer, who will not pay a price sufficient to admit of a good quality of iron being used. There is nothing so dear as cheap steel. It must be more economical to put five shillings' worth of labor upon steel that costs a shilling, to produce a tool that will last a week, than to put the same value of labor upon steel that costs only ninepence, to produce a tool that in mind that the elasticity of tempered will only last a day. The system adopted steel is acquired at the expense of its by some large consumers of buying best hardness. It is supposed that the maxitool steel by tender, is one which in too many cases defeats the object for which bined is obtained by tempering down to it was instituted, and by lessening the a straw color. In tempering steel, reprice, and consequently deteriorating the gard must be had to the quality most esquality, causes the steel bill to be appar-sential in the special tool to be tempered. ently lessened at the cost of the labor For example, a turning tool is required bill, so that extravagance instead of to be very hard, and is generally taken economy is the result. In fact it is an hot enough out of the water to temper illustration of the proverb about being itself down to a degree so slight that of firms in the steel trade habitually a spring is required to be very elastic, offer best cast steel at prices varying and may be tempered down to a blue. from forty to forty-five pounds a ton. Hardening in oil is a mode of treating

The statement that the steel supplied is the best that can be made may be accurately described by an ugly little word of three letters, and the firms which make it are liable to be suspected of "voluntary

The culminating point in the manufacture of tools made from steel, the final process which gives to them their most valuable properties—properties possessed by no other metallic substance—is that of tempering. The steel was originally lead; the process of hardening has turned it into glass; but we do not want glass—it is too brittle; we want whalebone. An unhardened knife would bend like wrought iron; a knife hardened only would break like cast metal. We want the elasticity of the whalebone. knife must spring like—like what?—like To attain this quality it must be steel.tempered. If a piece of hardened steel be heated slightly and then allowed to cool, it becomes tempered. It suddenly changes from glass to whalebone, and in the process of changing its nature it fortunately changes its color, so that the workman can judge by the color which it has assumed the extent of the elasticity which it has acquired, and can then give to each tool the particular degree of temper which is most adapted to its special The various colors through purpose. which tempered steel successively passes are as follows—straw, gold, chocolate, purple, violet and blue. Of course in passing from one color to another, the steel passes through the intermediate colors. It really passes through an infinite series of colors, of which the six above mentioned are arbitrarily selected as convenient stages. It must be borne mum of elasticity and hardness com-"penny wise and pound foolish." Scores no perceptible color is apparent; whilst

any scientific explanation of the change which takes place in the hardening and tempering of steel. All that chemists can yet do is to mystify their readers by writing unintelligibly about molecular rearrangement and crystalline transformation.

In speaking of the various foreign substances which are found in cast steel, I have confined myself, for the most part, to those which are supposed to be injurious to its quality; but before I close upon the various materials which are added to cast steel with the intention of improving it. If the steel manufacturers of Sheffield are not doctors of chemistry, they most of them practice as quacks. It has ever been a darling dream of the Sheffield steel melter to discover some substance—some philosopher's stone which will transmute common cast steel The various subinto best cast steel. stances used in the melting of cast steel, and supposed to have a chemical effect upon the material melted, are known by the technical name of "physic." The most universally used of these is peroxide of manganese, mixed with a little ground charcoal. Common salt, rock salt, salammoniac, chromate of potash, prussiate of potash, and even ground fluor spar and broken glass, form ingredients of the physic used by some steel melters. Manganese, either in the form of spiegeleisen, or of ferro-manganese, is also largely used, and has a definite effect upon the steel, it prevents, to a large extent, the formation of honeycombs in the ingot, and increases the welding capacity ed to a greater heat without cracking un-steel of a high quality. sion of the rolls; but it must be very of cast steel. cautiously used, as it undoubtedly inin the melting pot, instead of being pre-stand a sudden shock.

steel which is of special value for certain it materially assists its capacity to receive tools, and appears, to a certain extent, to a high polish; it increases its soundness, attain by one process the change from but makes it more brittle. Wolfram, or lead into whalebone without the passage tungsten, added in the form of a metallic through the intermediate glass stage. It alloy, is used to a considerable extent in is unfortunately not yet possible to give the manufacture of a special steel, sometimes called Mushet steel, which is frequently made so hard that it does not require to be hardened. It is used principally for turning tools, which, in consequence of the temper of the steel not being liable to injury by heat, can be driven at a higher speed than usual. Special steel of this kind is the finest grained that can be produced, but is so brittle that it can only be used by exceptionally skilled workmen. Chromium is sometimes used instead of wolfram, and my paper, a word or two must be said it is said that titanium is also employed, but I am not aware that any of the latter metal has yet been detected in steel by chemical analysis. A special steel for taps, called mild-centered cast steel, is made by converting a cogged ingot of mild cast steel so that the additional carbon only penetrates a short distance. These bars are afterwards hammered or rolled down to the size required, and have the advantage of possessing a hard surface without losing the toughness of the mild center.

It is much to be regretted that no easy method of testing cast steel has been invented. The amount of breaking strain, and the extent of the contractions of the area of fracture, give valuable information respecting iron or steel which is not hardened, and is not required to be used in a hardened state, but for hardened and tempered steel they are practically useless. It is very difficult to harden and temper two pieces of steel to exactly the same degree. A single test is of comparatively small value, as a secondrate quality of steel may stand very well the first time that it is hardened, but deof the steel; it gives the steel a greater teriorates much more rapidly every time tenacity when hot, so that it may be heat- it is rehardened than is the case with Nor is the der the blow of the hammer or the ten- breaking strain a fair test of the quality For many tools the capacity to withstand a high amount of creases the brittleness of the steel, and breaking strain, slowly applied, is not so its tendency to water-crack, if it be added much required as its capacity to with-The appearance viously suffused through the iron. Sili- of the fracture of cast steel is also very con is even more dangerous; it causes illusory. The fineness of the grain and the steel to crystallize in smaller crystals; the silkiness of the gloss are very capticold.

The consumer of steel may be enraptured, if he be of a poetical turn of mind, by the superb fracture of a bar of steel, reminding him of a picture by Ruskin of the aiguille structure of the higher Alps. But, after all, this is only a dodge, depending upon the inclination of the axis of the revolving hammer to the plane of the anvil. The practical consumer of steel must descend from the heights of art and science and take refuge in the commonplace of the rule of thumb, and buy the steel which he finds dexterity as the arts of skating, riding or of in his philosophy.

vating to the eye, but can be produced swimming. To arrive at perfection in by hammering the bar until it is almost these arts is difficult to those who do not inherit from skilled ancestors the facility to learn them; hence the trade has become localized in a few centers, of which Sheffield is the oldest and by far the most important. The arts of forging, hardening and tempering, which are necessary for the further manipulation of the steel after it leaves the hands of the manufacturer in Sheffield require equal dexterity, so that the art of steelmaking, if not mysterious, is very complicated. The real mystery lies in the chemical explanation of the effects produced, and when chemists have explained by experience to be full of "nature" and the phenomena of hardening and temper-"body." If I have been successful in ing steel, they may possibly discover why my attempt to explain the art and mys-cast steel made from Dannemora iron is tery of crucible cast steel making, you superior to the imitations of it. At preswill have understood that the converting, ent I presume that the candid chemist melting and forging of steel are three must admit that there are more things in arts, each of which requires as much best crucible cast steel than are dreamt

THE CAUSES AND REMEDIES OF CORROSION IN MARINE BOILERS.

By J. HARRY HALLETT.

From "Iron."

various ways to attain increased economy in its action; it attacks the metal in difof fuel in steamers. Among other means ferent parts of the boiler, in different of doing so, triple-expansion engines of high initial pressure are being introduced, which appear to be gaining much favor, and will no doubt in time supersede the ordinary two-cylinder type. The increased pressure of steam evidently renders it necessary to be still more guarded than hitherto as to the deterioration of boilers. Steel boilers are now in very to their efficiency; but the writer's experience is that they are equally liable with iron boilers to corrosive influences. On careful scrutiny he has found in steel

Marine engineers are all striving in | corrosion is well known to be most erratic ways, and from various causes. principal sources of corrosion, however, may be discussed under the two heads of defective design and defective management: which is equivalent to saying that an ordinary marine boiler will hardly be subject to corrosion at all, if well designed and well managed.

Design.—The most frequent fault of general use, and there can be no doubt as design which bears upon corrosion is the want of sufficient space for allowing a thorough examination to be made of every part of the boiler. The tubes are often placed so far out in the wings that it is plates severe corrosion concealed by a impossible to get down to look at the very slight scale, upon the removal of sides of the furnaces, or so close to the which the plate has proved to be covered furnace crowns that there is no room to with a black substance, probably a black get over these. It would be preferable oxide of iron. In many cases a casual in- to allow at least nine inches between each spection may fail to detect this. Internal furnace crown and the bottom row of

tubes, especially as this row is not useful so as first to warm the water inside it, as heating surface when placed so close down to the crown. The manholes are often inconveniently placed and made too small, which always affords an excuse for want of proper attention on the part of the men in charge. Manholes should always be fitted in the wings if the size of boiler will allow. There can be no doubt always be blown off upon raising steam, that the best way to prolong the life of a boiler is to watch it carefully and constantly, so as to note the commencement of deterioration and take steps to check it. In any part which cannot be seen, it is impossible to know what is going on. Another fault of design, which easily escapes notice until too late, is the pitching of the steam-space stays, so that one or perhaps several of them come over a space, instead of over a tube, thus rendering the effective use of the scaling tool very difficult, or even impossible in that particular vertical space. With the object of securing the conventional 20 square feet of heating surface per horse-power, the tubes are sometimes too closely pitched, which causes bad circulation, besides rendering the spaces liable to become soon choked with scale. The tubes should never be less than 11 inch apart, both vertically and horizontally.

Management.—The first point to be looked to in the management of a boiler is the circulation. In an ordinary multibular marine boiler the circulation takes place by the water ascending from the furnace crowns, and from the sides, backs, and fronts of the combustion chambers, and descending at the wings; the tubes do, of course, somewhat obstruct the upward current. There can be no doubt that the coolest places in the boiler are those where the circulation is most defective, as is naturally the case below the level of the fire-bars. The water in this part of the boiler always contains the greatest were under steam about seventy-two percentage of solid matter, and here the greatest deterioration may, therefore, be expected to be found. Double-ended boilers are not only subject to the same indication of pitting or corrosion. corrosive action as single-ended ones, but reducing this difference as far as possible, led along on a level with the upper tubes, steam is raised to about 30 lbs, per square

and is thence carried down so as to discharge the warmed water in a horizontal direction at the bottom of the boiler. The scum pipe should be fitted with a pan, shaped like an inverted saucer, and placed just above the level of the water for the scum to collect under it; and it should and also about once a day when under weigh. The blow-off cock should either be attached at the bottom of the boiler, or else an internal pipe should be fitted to it, reaching down to the very bottom. Salt is not deposited until the density of the water exceeds 4-32ds by the salinometer, that is, until there is more than 4 lbs. of salt in 32 lbs. of water; beyond this proportion the deposition of salt then begins upon the furnace crowns, &c. It is recommended that the opportunities occurring from time to time by the engines being stopped should be taken advantage of for pumping up the boiler to the top of the gauge glass, and then blowing it down to the bottom of the glass. This, repeated about twice or thrice on each occasion, will work wonders. The great usefulness of this plan arises from the fact that while the engines are stopped there is little or no steam being made, and therefore no solid matter is being deposited from the water; so that the extra feed-water pumped in at that time does much more to freshen the boiler than it would if the engines were at work. When in charge of the engines of a steamer on a voyage from England to Rangoon, calling at several ports on the way, and thence to Venice, the writer kept water in the boilers continuously during the whole round; that is to say the boilers were never entirely run out and refilled, but were blown down from time to time as above described. days, and upon being opened out at the end of that time had only a slight scale upon them of uniform thickness, and no

The mode of treatment adopted by the being longer they are also more prone to writer for new boilers is to have them suffer from racking strains, due to the well washed out before filling, then to difference of temperature between their run them up, and when they are filled upper and lower parts. One method of with water up to the normal height, to throw into each through the top manhole is to fit the internal feed-pipe so that it is about a bucketful of common soda. When

inch, blow out a little through the scum supervision. Another great evil is raising cock. Before adding any more water, steam too quickly, and blowing out under start the feed donkey, and let it deliver too great a pressure, which cannot be too for sometime over the side of the ship, so as to get rid of any dirt, &c., in the pump; this is a very useful precaution to observe whenever the feed donkey is employed. After starting the main engines, let them run at first with the feed water overflowing from the hot well into the bilges; this will clear the condenser. When under weigh, it is advisable to use the blowdown cocks sparingly. The appearance of the water in the gauge glass shows at a glance the state of the water in the boiler; if the glass is at all dirty inside, that is proof positive of the water not being clean enough; and this can be cured by the use of the scum cock. In a double-ended boiler a scum pipe should be fitted at each end. The scum pipes are sometimes so fitted that their position can be altered to suit the trim of the ship, which is a point of far more importance than is generally imagined. After a run, when steam is finished with, the water should be blown out from the bottom and the boilers then kept thoroughly dry. Before refilling they should be carefully swept down inside, and washed out. There is no doubt that one of the most active causes of deterioration in boilers is the want of proper care in their treatment. Cases have come under the author's notice of boilers being blown down as far only as the level of the bottom manholes, and refilled, without care being taken to draw the water out of the bottoms. This process having been frequently repeated, the water at the bottoms became so impregnated that the heads of the rivets and the lower half of the compensating rings round the manholes were corroded away, while the other parts of the boilers were in good condition. Many good boilers are ruined through careless management, and the makers are wrongly charged with allowing their work to come from the shop not properly finished. Another example, out of numerous cases met with, is that of a pair of boilers which were fitted some little time ago with hydro-kineters, or internal steam-jet nozzles for stimulating the circulation of the water in the cooler places below the furnace flues. Upon a recent examination the valves of these appliances were found to be hard and time, and corrosion had been going on

strongly condemned. Corrosion in the upper parts of the boiler is principally caused by the introduction of oil, tallow, and other greasy substances from the engines. In all the steamers with which the writer is connected he has discarded the use of all oil or other lubricant in the cylinders, with the most satisfactory results.

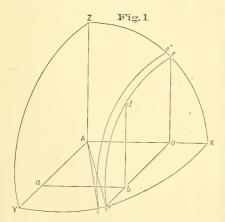
Various remedies have been suggested for preventing corrosion; among others, air-extractors and circulating tubes. Zinc has been tried, both cast and rolled, and some engineers report favorably on its use; but to make it effective, very large quantities must be used, as it so quickly oxidizes, and thus loses its protective qualities. The electrogen of Mr. Hannay's invention, which is rapidly gaining favor, is a very simple little appliance, and, as far as the writer has experimented with it, is very effective. The principle upon which it works is the setting up of a small galvanic battery in the boiler, by mans of a ball of zinc cast upon a copper bar, and then hammered, to make it more impervious to the action of the water; on each end of the copper bar a wire is soldered, and the two wires are again soldered to different parts of the boiler, so as to obtain metallic contact. Boilers which had shown a tendency to corrosion looked quite healthy in a very short time after these appliances had been fitted to them. Marine boilers are not troubled with much external corrosion, especially modern boilers, because much more care is now taken in fitting them into the ships than was formerly the case. They are now properly coated, and are not fitted too close down to the bottom of the ship, plenty of room being allowed for access to the seams. But that all the mischief to be contended with is not confined to the waterside of the boiler is shown by the following incident. Some four and a half years ago the writer was called in to survey a boiler that had exploded and killed the chief engineer and firemen. examination it was found that the bridges had been built up close to the backs of the combustion chambers; the dirt, &c., had been allowed to accumulate for some fast, in consequence of carelessness in upon both sides of the plate without being noticed. After the accident, when all like cleanliness to prolong the life of a had been cleared away, the iron was found boiler. When a vessel is to be laid up, a to have oxidized so much that in some good plan is to pump the boiler full up to parts it was barely 1-16th of an inch thick; the very top of the dome, and keep it so hence the explosion. The backs had been until it is again required. Another methso built up for the express purpose of od of preserving a boiler not in use is to economising fuel; but experience goes to empty it and clean it thoroughly, then prove that this is a fallacy, and many cases close all the manhole doors except one at could be mentioned where similar bridges the bottom, put in a small stove full of have been taken out without making any burning coke, and close up the bottom difference in consumption of fuel, except door quickly. The object of both these that, if anything, the economy had been in methods is, of course, to exclude air as favor of their absence. There is nothing thoroughly as possible.

GENERAL DISCUSSION OF WIND PRESSURE UPON SPHERI-CAL, CYLINDRICAL, AND CONICAL SURFACES.

By P. H. PHILBRICK.

Written for Van Nostrand's Engineering Magazine.

Let XYZA represent one fourth of the windward half of a spherical dome; XA the direction of the wind, inclined to the horizon at angle a; cde and c'e' two arcs near together in planes parallel to YAZ, and O the center of cde.



 $OAc = i \ cAc' = di$, $r = radius \ of the dome$.

Let P equal the pressure upon a unit of plane surface normal to the direction of the wind; N = the normal pressure upon any surface; X, Y, Z, the x, y and zcomponents of the pressure.

We have, co=r sin. i, $cde=\frac{\pi}{2}$ r sin. i, cc' = rdi;

... the area of the band

$$cde \ c'e' = \frac{\pi}{2}r^2 \sin i \ di. \quad (1)$$

According to Duchemin (see "Annals of Mathematics," vol. 1, No. 2, p. 47) the pressure upon a unit area of surface is

 $\frac{P}{1+\frac{1}{2}\tan^2 i}$, i being the angle of incidence.

Hence the pressure on the band is

$$dN = \frac{P}{1 + \frac{1}{2} \tan^2 i} \cdot \frac{\pi}{2} r^2 \sin i \, di =$$

$$= P \pi r^2 \frac{\sin i \, di}{2 + \tan^2 i} \quad . \quad . \quad (2)$$

$$= P\pi r^{2} \frac{\cos^{2} i \sin i di}{1 + \cos^{2} i} = P\pi r^{2} \left(\frac{d \cos i}{1 + \cos^{2} i} - d \cos i\right)$$
(3)

$$\therefore N = P\pi r^2 \int \left(\frac{d \cos i}{1 + \cos^2 i} - d \cos i \right) -$$

$$= P\pi r^2 \left\{ \tan \cos i - \cos i \right\}_{\circ}^{\frac{\pi}{2}} . \tag{4}$$

$$= P\pi r^{2} \left(1 - \frac{\pi}{4}\right) = .4292 P \times \frac{1}{2} \pi r^{2} =$$

$$= .6742 Pr^{2}. (5)$$

On the dome the pressure is $4 \text{ N} = .4292 \text{ P} \times 2\pi r^2 = 1.3484 \text{ P}r^2$. (6) The average normal pressure is, there-

fore equal to .4292 $P = \left(2 - \frac{\pi}{2}\right)P$.

To find X. We have, dX=dN cos. i; \therefore from (4),

$$X = P\pi r^{2} \int \left(\frac{\cos i d \cos i}{1 + \cos^{2} i} - \cos i d \cos i \right)$$

$$= \frac{1}{2} P\pi r^{2} \left\{ \log (1 + \cos^{2} i) - \cos^{2} i \right\}_{\circ}^{\frac{\pi}{2}} =$$

$$= \frac{1}{2} P\pi r^{2} (1 - \log 2) = .6136$$

$$P \times \frac{1}{4} \pi r^{2} = .4821 Pr^{2} . . . (7)$$

For the whole wind pressure

$$4X = .6136 \text{ P} \times \pi r^2 = 1.9284 \text{ P} r^2$$
 . (8)

Hence the X component of the pressure is equivalent to a pressure of .6136 P on each unit of the meridian plane YAZ.

The horizontal shearing strain between the dome and its supports, which is equal to the transverse shearing strain of the supports, is evidently= $4X \cos a$.

The moment of the wind pressure about the foot of the supports is equal to 4Xh cos. a, h being the height of the supports.

TO FIND THE COMPONENT Z.

The pressure on the band being constant the Z component of that pressure will be equal to the pressure multiplied by the length of the average ordinate (z say), divided by r. This ordinate is equal to the distance of the center of gravity of the quadrant cde from co.

Now,
$$z = \frac{2}{\pi} Oe = \frac{2}{\pi} r \sin i$$
, $\frac{z}{r} = \frac{2}{\pi} \sin i$.

Hence, by (3), $Z=2Pr^2\int \frac{\cos^2 i \sin^2 i \, di}{1+\cos^2 i}$

$$= 2 \Pr^{2} \int \frac{\sin^{2} i - \sin^{4} i}{1 + \cos^{2} i} di. \quad (9)$$

$$=2 \operatorname{Pr}^2 \int \left(\sin^2 i + 1 - \frac{2}{2 - \sin^2 i} \right) di$$
, by

partial fractions.

$$=2\Pr^{2} \left\{ \int (\sin^{2}i + 1) \ di - \int \frac{\frac{1}{2}\sqrt{2}di \ i}{\sqrt{2} + \sin i} \right.$$

$$\left. - \int \frac{\frac{1}{2}\sqrt{2}di}{\sqrt{2} - \sin i} \right\} \text{ similarly.} \quad (10)$$

$$\text{Now, } \int \frac{di}{\sqrt{2} + \sin i} = \frac{2}{(2-1)\frac{1}{2}} \tan^{-1}$$

$$\left\{ \frac{\sqrt{2}}{(2-1)^{\frac{1}{2}}} \left(\tan \frac{i}{2} + \frac{1}{\sqrt{2}} \right) \right\} = 2 \tan^{-1}$$

$$\left\{ \sqrt{2} \left(\tan \frac{i}{2} + \frac{1}{\sqrt{2}} \right) \right\} \begin{vmatrix} \therefore dm = dX. \\ i \sin i d N. \end{vmatrix}$$

Similarly,
$$\int \frac{di}{\sqrt{2} - \sin i} = 2 \tan^{-1} \left\{ \sqrt{2} \left(\tan \frac{i}{2} - \frac{1}{\sqrt{2}} \right) \right\}$$

$$\therefore Z = 2Pr^2 \left[\frac{i - \sin i \cos i}{2} + i - \sqrt{2} \tan^{-1} \left\{ \sqrt{2} \left(\tan \frac{i}{2} + \frac{1}{\sqrt{2}} \right) \right\} - \sqrt{2} \tan^{-1} \left\{ \sqrt{2} \left(\tan \frac{i}{2} - \frac{1}{\sqrt{2}} \right) \right\} \right]_{\circ}^{\frac{\pi}{2}}$$

$$= 2Pr^2 \left\{ \frac{3\pi}{4} - \sqrt{2} \tan^{-1} \left(\sqrt{2} + 1 \right) - \sqrt{2} \tan^{-1} \left(\sqrt{2} - 1 \right) \right\} = 2Pr^2 \left(\frac{3\pi}{4} - 2\sqrt{2} \tan^{-1} 1 \right)$$

$$=2 \operatorname{Pr}^{2} \left(\frac{3\pi}{4} - \sqrt{2} \cdot \frac{\pi}{2} \right) = \frac{1}{2} \operatorname{P} \pi r^{2} (3 - 2\sqrt{2})$$

$$= .3432 \operatorname{P} \times \frac{1}{4} \pi r^{2} = .2695 \operatorname{Pr}^{2}. \quad (11)$$

The Z components of the pressure, above and below the plane XAY, are each equal to $2Z=.5391 Pr^2$ (12)

Similarly the Y components on either side of the plane XAZ are each equal to $2Y=.5391 Pr^2$ (12)

The wind tends, therefore, to compress and distort the dome laterally and vertically, but not in the direction of the wind.

For a hemispherical dome, with the wind horizontal, we have from equations (5), (7) and (11),

$$2N = .4292 P\pi r^2$$
 . . (13)

$$2X = .6136 \text{ P} \frac{1}{3}\pi r^2$$
 . (14)

$$2Z = .3432 P_{\frac{1}{2}} \pi r^2$$
 (15)

$$Y = .3432 P_{\frac{1}{4}} \pi r^2$$
 . (16)

In this case the additional load due to the wind pressure is, $.3432 \text{ P}_{2}^{1} \pi r^{2}$, given by (15).

TO FIND THE POINT OF APPLICATION OF X.

The moment of dX about A is equal to dX multiplied by the distance of the center of gravity of cde from cO.

$$\therefore dm = dX. \frac{2}{\pi} cO = dX \frac{2}{\pi} r \sin i = \frac{2}{\pi} r \cos i$$

$$i \sin i dX.$$

Hence, by (3) we have, M=2 Pr³

$$\int \frac{\sin^{2}i \cos^{3}i \, di}{1 + \cos^{2}i} . \quad (17)$$
Now $\int \frac{\sin^{2}i \cos^{3}i \, di}{1 + \cos^{2}i} = \int \cos i$

$$\left(\frac{2 \cos^{2}i}{1 + \cos^{2}i} - \cos^{2}i\right) di =$$

$$= \int \left(2 \cos i - \cos^{3}i - \frac{2 \cos i}{1 + \cos^{2}i}\right) di$$

$$= \int \left(2 \cos i - \cos^{3}i\right) di - 2$$

$$\int \frac{d \sin i}{2 - \sin^{2}i} . \quad (18)$$

$$= \begin{cases} 2 \sin i - \frac{\sin i \cos^{2}i}{3} - \frac{2}{3} \sin i + \frac{1}{\sqrt{2}} \\ \log \left(\sqrt{2} - \sin i\right) - \frac{1}{3} \end{cases}$$

Now
$$\frac{M}{X} = \frac{.1736Pr^s}{.4821Pr^2} = .3601r = \overline{Z}$$
 (21)

Since $.3601=\sin^{-1}21^{\circ}6'$, the point is $21^{\circ}6'$ from X on the arc XZ.

In a similar manner we have for Z, $dM' = dZr \cos i$, which with (9) gives,

$$\mathbf{M}' = 2 \operatorname{Pr}^{3} \int \frac{\cos^{3} i \sin^{2} i \, di}{1 + \cos^{2} i}$$
 which is the

same as (17).

Hence
$$M' = M = .1736 \text{ P}r^3$$
 . . (22)

This follows, indeed, from elementary principles; for, since the pressure on the dome is normal to the surface, the total moment about A is equal to zero; or the moment of X is equal to the moment of Z.

Now
$$\frac{M'}{Z} = \frac{.1736 \,\mathrm{P}r^3}{.2695 \,\mathrm{P}r^2} = .6440 \,r$$
 (23)

The point is therefore $40^{\circ}5'27''$ from Z on the arc ZX.

Dividing (11) by (7) gives, $\frac{.2695}{.4821}$ = .55901 = tan. 29°12′20″, the angle made by the resultant wind pressure with the horizon.

The moments of X and Z about the center of the base of the dome being equal, it follows that the excess of the moment of X over that of Z about the foot of the supports, is equal to Xh, h being the height of the supports. This is the moment of the force that inclines the dome to the leeward.

Since the Y and Z components of the pressure on the part of the dome shown in the figures are equal, the resultant R of the normal pressure is,

$$R = (X^{2} + 2Z^{2}) \frac{1}{2} = 2Pr^{2} [(.4821)^{2} + 2 (.2695)^{2}] \frac{1}{2} = .6145 Pr^{2} . . . (24)$$

Again, since the sum of the Y components on the whole dome is equal to zero, we have for the resultant of the whole normal pressure,

$$R = [(2X)^{2} + (2Z)^{2}]^{\frac{1}{2}} = Pr^{2}[(.9642)^{2} + (.5391)^{2}]^{\frac{1}{2}} = 1.1047 Pr^{2} . . (25)$$

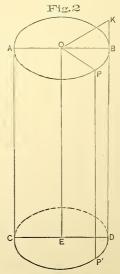
The angle between the two partial resultants is given by,

$$\cos \theta = \frac{R_1^2 - 2R_2^2}{2R^2} = \frac{X^2}{X^2 \times 2Z^2} = .6154.$$

 $\therefore \theta = 52^{\circ}1'$. The partial resultants therefore, make an angle of 26°30" with the plane XZ.

The pressure on the plane XZ is, therefore, R sin. $26^{\circ}30'' = .6145 \text{ PR}^2 \times .4385 = .2695 \text{ PR}^2$, which is the pressure in the direction YA (26)

This agrees with (11).



Let ABCD represent a cylinder with

the axis vertical; r=radius, l=length. Let K O be the direction of the wind, and P any point on the surface.

Let KOB=a, BOP=i and $KOP=\theta$. Now cos. $KOP=\cos$. KOB cos. BOP;

or $\cos \theta = \cos a \cos i$.

Hence,

$$\frac{1}{1 + \frac{1}{2} \tan^{2} \theta} = \frac{2 \cos^{2} \theta}{2 \cos^{2} \theta + \sin^{2} \theta}$$

$$= 2 \frac{\cos^{2} a \cos^{2} i}{1 + \cos^{2} a \cos^{2} i}$$

$$= 2 \left(1 - \frac{1}{1 + \cos^{2} a \cos^{2} i}\right)$$

$$= 2 \left(1 - \frac{1}{\sin^{2} i + (1 + \cos^{2} a) \cos^{2} i}\right)$$

The area of an elementary strip adjacent to the element PP' is equal to rldi. Hence the normal pressure

=2N=2rPl

$$\int \left(di - \frac{di}{\sin^2 i + (1 + \cos^2 a)\cos^2 i} \right)^{\frac{\pi}{2}} \times 2$$

$$= 4r \operatorname{P} l \left\{ i - \frac{1}{(1 + \cos^2 a)^{\frac{1}{2}}} \tan^{-1} \right\}$$

$$\frac{1}{(1 + \cos^2 a)^{\frac{1}{2}}} \tan i \cdot i \cdot \int_{\frac{\pi}{2}}^{\frac{\pi}{2}}$$

$$= 4r \operatorname{P} l \left(\frac{\pi}{2} - \frac{1}{(1 + \cos^2 a)^{\frac{1}{2}}} \frac{\pi}{2} \right)$$

$$= \pi r \operatorname{P} l \left(2 - \frac{2}{(1 + \cos^2 a)^{\frac{1}{2}}} \right). (27)$$

If
$$a=o$$
, $2N = \pi r \operatorname{Pl} (2-\sqrt{2}) = = .5858 \operatorname{P} \pi r l$. . (28)

The average normal pressure is, therefore, .5858 on each unit.

The pressure in the direction BO is, evidently

$$2H = 2Prl \int \left(\cos i \, di - \frac{\cos i \, di}{\sin^2 i + (1 + \cos^2 a)\cos^2 i}\right)^{\frac{\pi}{2}} \times 2$$

$$= 4Prl \int \left(d\sin i - \frac{1}{\cos^2 a}\right)^{\frac{\pi}{2}} \times 2$$

$$= 4Prl \left(\sin i - \frac{1}{\cos^2 a} - \sin^2 i\right)$$

$$= 4Prl \left(\sin i - \frac{1}{2\cos a} \frac{1}{(1 + \cos^2 a)^{\frac{1}{2}} + \cos a \sin i}\right)^{\frac{\pi}{2}}$$

$$\log \frac{(1 + \cos^2 a)^{\frac{1}{2}} + \cos a \sin i}{(1 + \cos^3 a)^{\frac{1}{2}} - \cos a \sin i}\right)^{\frac{\pi}{2}}$$

$$=4\Pr[1-\frac{1}{2\cos a(1+\cos^{2}a)^{\frac{1}{2}}}\log .$$

$$\frac{(1+\cos^{2}a)^{\frac{1}{2}}+\cos a}{(1+\cos^{2}a)^{\frac{1}{2}}-\cos a} . . (29)$$

If a=0,2H=4 Prl

$$\left(1 - \frac{1}{2\sqrt{2}}\log \frac{\sqrt{2+1}}{\sqrt{2-1}} = .7536P \times 2rl(30)\right)$$

This is equivalent to .7536 P on each unit of the meridian plane.

The lateral pressure, normal to the plane ABCD, is evidently,

$$Y=2 \operatorname{Prl} \int \left(\sin i \, di - \frac{\sin \cdot di}{1 + \sin^2 a \, \cos^2 i}\right)$$

$$=2 \operatorname{Prl} \int \left(\sin i \, di - \frac{1}{\cos^2 a}\right)$$

$$=\frac{\sin i \, di}{1 + \cos^2 a}$$

$$=2 \operatorname{Prl} \left\{-\cos i - \frac{1}{\cos a}\right\}$$

$$=2 \operatorname{Prl} \left\{-\cos a \cos i\right\}_{0}^{\frac{\pi}{2}} . (31)$$

$$=2 \operatorname{Prl} \left(1 - \frac{1}{\cos a} \tan^{-1} \cos a\right) . (32)$$

$$\begin{array}{ccc}
\cos a & \cos a
\end{array}$$

$$\begin{array}{ccc}
\cos a & \cos a
\end{array}$$

$$\begin{array}{cccc}
\cos a & \cos a
\end{array}$$

$$\begin{array}{cccc}
-4999 \operatorname{Pai} & (22)
\end{array}$$

If
$$a=o$$
, $Y=Prl\left(2-\frac{\pi}{2}\right)=.4292 \, Prl$. (33)

This is equivalent to a pressure of .4292 P on each unit of the plane OBD.

The shearing strain is given by (30), and is, H=1.5072 Prl.

The moment of H about the foot of the supports is H $(\frac{1}{2}r+h)$, h being the height

of the supports.

If the axis of the cylinder is horizontal, N and H are given as before, and Z, which is the same as Y in the preceding case, is given, of course, by equations (32) and (33.)

Let β in the angle between the direction of the wind and the horizon. This is equal to the angle between H and the horizon, or Z and the vertical plane through the axis of the cylinder.

The moment of H about the foot of the supports is therefore, H $(\frac{1}{2}r+h)$ cos. β .

Let us consider a right cone standing upon its base.

Let 2r=the vertical angle of the cone.

Let a= the angle between the direction of the wind and the normal to the axis, the angle being considered positive downward.

a+v=the angle between the direction of the wind and the normal to the element of the cone on the windward side.

Substituting this for a, and the convex surface of the cone for that of the cylinder in eqs. (27), (29) and (32), we have,

$$2N = \frac{1}{2} P \pi r l \left(2 - \frac{2}{(1 + \cos^2(a + v))^{\frac{1}{2}}} \right)$$
(34)

2H=2Prl

$$\left(1 - \frac{1}{2\cos.(a+v)[1+\cos.^{2}(a+v)]^{\frac{1}{2}}} \log. \frac{(1+\cos.^{2}(a+v))^{\frac{1}{2}} + \cos.(a+v)}{(1+\cos.^{2}(a+v))^{\frac{1}{2}} - \cos.(a+v)}}{(35)}\right).$$

$$Y = Prl$$

$$\left(1 - \frac{1}{\cos(a+v)} \tan^{-1} \cos(a+v)\right)$$
. (36)

If the wind is horizontal, a=0, and the above equations become,

$$2N = \frac{1}{2} \Pr l \left(2 - \frac{2}{(1 + \cos^{2}v)^{\frac{1}{2}}} \right) . . . (37)$$

$$2H = 2 \Pr l \left(1 - \frac{1}{\cos v \cdot (1 + \cos^{2}v)^{\frac{1}{2}}} \log. \frac{(1 + \cos^{2}v)^{\frac{1}{2}} + \cos r}{(1 + \cos^{2}v)^{\frac{1}{2}} - \cos r} \right) . (38)$$

$$\mathbf{Y} = \left(1 - \frac{1}{\cos v} \tan^{-1} \cos v\right) \quad . \tag{39}$$

If a = -v, the wind is normal to the element of the cone on the windward side, and equations (34), (35) and (36), become,

$$2N = \frac{1}{2} \pi r Pl (2 - \sqrt{2})$$
 . . . (40)

$$2H = 2Prl\left(1 - \frac{1}{2\sqrt{2}}\log \frac{\sqrt{2+1}}{\sqrt{2-1}}\right).$$
 (41)

$$Y = \frac{1}{2} Prl\left(2 - \frac{\pi}{2}\right)$$
 (42)

These equations are just one half of equations (28), (30), and (33), as they ought to be, since the surface of the cone is one-half that of the cylinder.

The moment of H about the foot of the supports is evidently

$$M=H(\frac{1}{3}l+h)\cos a$$
 . . . (43)
Which becomes, $M'=H(\frac{1}{3}l+h)$ when the wind is horizontal (44)

If the apex is downward, equations $(34)\dots(39)$ apply by putting -v for v. -v however, gives the same results as +v in equations (37), (38), and (39), as it

ought to do. The moment of H is the same as when the apex is uppermost, with $\frac{2}{3}l$ substituted for $\frac{1}{3}l$.

If the axis of the cone is horizontal, the same equations apply, as sufficiently explained with reference to the cylinder.

It is evident that the equations apply directly to a frustum of a cone, the convex surface of the frustum being substituted for the convex surface of the conein the preceding equations.

II. Let us suppose the pressure upon a unit of area of surface to be, P $\cos i =$

 $\frac{1}{\sec i}$, i being the angle of incidence as. before. Let us consider a hemispherical dome. Then the pressure on the band cdec'e' in Fig. 1 is

$$d$$
 N=P cos. $i \cdot \frac{\pi}{2} r^2 \sin i di =$
= $\frac{1}{2}$ P $\pi r^2 \cos i \sin i di$. (45)

$$\therefore N = -\frac{1}{4} P \pi r^2 \left\{ \cos^2 i \right\}_0^{-\frac{\pi}{2}} =$$

$$= \frac{1}{2} P \times \frac{1}{2} \pi r^2 = .7854 P r^2 . (46)$$

On the whole dome, $2N = \frac{1}{2}P \times \pi r^2$. (47)

The average normal pressure is therefore equal to $\frac{1}{2}$ P.

From (45),
$$dX = dN \cos i = \frac{1}{2} P \pi r^2 \cos^2 i \sin i \ di$$

$$\therefore X = \frac{1}{2} P \pi r^2 \int \cos^2 i \sin i \, di = -\frac{1}{6}$$

$$P\pi r^{2} \left(\cos^{5} i\right)_{0}^{\frac{\pi}{2}} = \frac{1}{6} P\pi r^{2}.$$
 (48)
and $2X = \frac{2}{2} P \frac{1}{2} \pi r^{2} = \frac{1}{6} P\pi r^{2}.$ (49)

and
$$2X = \frac{2}{3}P\frac{1}{2}\pi r^2 = \frac{1}{3}P\pi r^2$$
. (49)

Hence the X component of the pressure is equivalent to a pressure of $\frac{2}{3}$ P on each unit of the meridian plane YAZ.

TO FIND THE MOMENT AND THE POINT OF APPLICATION OF X.

The moment of dX about the point X is.

$$d\mathbf{M} = d\mathbf{X} \cdot \frac{2}{\pi} c\mathbf{O} = d\mathbf{X} \frac{2^{\circ}}{\pi} r \sin i \mathbf{i} =$$

$$= \mathbf{P} r^{3} \cos^{2} i \sin^{2} i \, di. \quad (50)$$

$$\therefore \mathbf{M} = \mathbf{P}r^{3} \int \left(\sin^{2}i \, di - \sin^{4}i \, di\right) = \mathbf{P}r^{3}$$

$$\left\{i - \frac{\sin i \cos i + 2 \sin^{3}i \cos i}{8}\right\}_{\circ}^{\frac{\pi}{2}} =$$

$$= \frac{\pi}{16} \mathbf{P}r^{3}. \quad (51)$$

Now
$$\frac{M}{X} = \frac{3}{8} r = \sin^{-1} 22^{\circ} 1' 27''$$
 . (52)

giving the point of application.

TO FIND THE VERTICAL COMPONENT Z.

From (45) and the equations preceding (9), the vertical component of the pressure on the band

$$= d\mathbf{Z} = \frac{2}{\pi} \sin i \times \frac{1}{2} \mathbf{P} \pi r^2 \cos i \sin i di =$$

$$= \mathbf{P} r^2 \cos i \sin^2 i di. \quad (53)$$

$$\therefore Z = Pr^2 \int \sin^2 i \cos i \, di = \frac{1}{3} Pr^2$$

$$\left\{ \sin^3 i \right\}_{\circ}^{\frac{\pi}{2}} = \frac{1}{3} \Pr^2.$$
 (54)

and 2Z =

$$\frac{2}{3} \Pr^2$$
. (55)

TO FIND THE MOMENT AND THE POINT OF APPLICATION OF Z.

Moment of $d Z=d M'=d Z \cos i= Pr^3$ $\cos^2 i \sin^2 i \, di$, which is the same as (50).

Hence,
$$M' = \frac{\pi}{16} Pr^3$$
.

and
$$\frac{M'}{Z} = \frac{3\pi}{16}r = .589r = \sin^{-1} 36^{\circ} 5' 20''$$
.

Now the resultant, $R = (X^2 + 2Z^2)^{1/2}$

$$= Pr^{2} \left[(.5236)^{2} + 2 \left(\frac{1}{3} \right)^{2} \right] = Pr^{2}$$

$$(.27415696 + .22222222) \frac{1}{2} = .70454 Pr^{2}.$$

Also R'=[
$$(2X)^2+(2Z)^2$$
] $\frac{1}{2}$ = $(1.09662784+.44444444) $\frac{1}{7}$ =1.2414 Pr².$

The angle between the two partial resultants is given by,

cos.
$$\theta = \frac{X^2}{X^2 + 2Z^2} = \frac{.27415696}{.49637918} = .55231$$

$$\theta = 56^{\circ}28'28'' \text{ and } \frac{\theta}{2} = 28^{\circ}14'14'' \text{ the }$$

angle the partial resultants make with the plane XZ.

The pressure on the plane XZ is, therefore, R sin.

$$28^{\circ}14'14'' = .70454Pr^{2} \times .47312 = \frac{1}{3}$$

 $Pr^{2} = Z = Y$, as before found. (56)

From (54) and (48) we have,

$$\frac{Z}{X} = \frac{2}{\pi} = .63662 = \tan .32^{\circ}28'54''$$
 which is

the angle the resultant makes with the

It is probable, too, that the former results agree more nearly with experiments than the latter. The latter results are always greater than the former, as I will now show; and so probably err on the safe

We have,
$$\frac{\cos i}{1} = \frac{1}{\sec i} = \frac{1}{(1 + \tan^2 i)^{\frac{1}{2}}}$$

and $\frac{1}{1 + \frac{1}{2} \tan^2 i} = \frac{1}{(1 + \tan^2 i + \frac{1}{4} \tan^4 i)^{\frac{1}{2}}}$.

We see that the above formulas meet, in general, every practical demand in reference to domes and their supports. They apply, also to the parts of bridges, including suspension cables, ropes and wires for the transmission of power, telegraph wires, etc. Also to water tanks, stand pipes, chimneys, towers, columns, etc.

The writer expects to deal still further with the general subject in a future article.

REPORTS OF ENGINEERING SOCIETIES.

Record of Regular Meeting, October 18th, 1884. President William Ludlow in the chair. Mr. C. Henry Roney showed a Portable Storage Battery for Mining and Exploring Purposes, with small incandescent lamps, illustrating his remarks with blackboard sketches. The bat-tery shown was a modification of Planté's, devised by Dr. E. T. Starr, of Philadelphia, the electrodes consisting of V-shaped plates of shect lead arranged over each other, the convexity downwards, with a slight interval between them, their ends attached to a lead frame by "burned" joints, the interstices between the plates being filled with finely divided metallic lead, exposing a large surface to oxidation and reduction when subjected to dynamic electric or voltaic energy, and, in turn, giving off a large percentage of the "stored" energy to incandescent lamps placed in the circuit. The battery shown measured 31 inches long, $2\frac{3}{4}$ inches high, and $\frac{3}{4}$ inch thick, and would maintain a small two-candle incandescent lamp at incandescence for about one hour. A battery sufficiently large to run an eight-candle lamp for ten or twelve hours would not be too large or heavy to carry conveniently for mine or other underground exploration.

Mr. W. L. Simpson exhibited and described the Thompson Indicator. He considers it the Thompson Indicator. He considers it handsome in design, and convenient and simple in arrangement. Cards can be taken with it at as high a pressure as 500 lbs. per square inch. All the moving parts are made very light and strong, which is a consideration of much importance in an indicator, especially plane XY.

As other results, in the light of the above, are easily found, it is not necessary to extend this part of the subject.

As other results, in the light of the above, are easily found, it is not necessary to extend this part of the subject. taken up as may be desired. This is quite an improvement, as, formerly, a whole coil of the spring had to be taken up or none at all. By means of a jamb nut the horn handle screw can be set so as to regulate the pressure of the pencil on the paper, the back of the screw touching against a small post, and thus avoiding any strain tending to throw the parts out of line through too much pressure. To exchange springs is very easy, it only being necessary to unscrew the milled nut at the top of the steam cylinder, take out the piston with its arm and connections, disconnect the lever and piston by unscrewing the small knnrled-headed screw which connects them, when the spring can be removed from the piston and the desired one substituted.

All springs made for this indicator are scaled, providing for 30 inches vacuum; and the capacity of any spring can be ascertained by a simple rule. To adapt the Thompson indicator to all pressures, springs can be made to any desired scale. The following are the most generally used: 8, 10, 12, 16, 20, 24, 30, 32, 40, 48, 50, 56, 60, 64, 80, 100. For pressures from 65 to 85 lbs. a 40 lb. spring is best adapted, for as 40 lbs. pressure on a 40 lb. spring will raise pencil one inch, 85 lbs. pressure on the same spring will raise pencil about two inches, which is the usual height of a diagram.

By means of the "detent motion," consisting of a pawl and spring stop, the paper cylinder can be stopped and the card taken off without unhooking the connecting rod. rangement of a swivel carrying a scored wheel allows the connecting cord to be run at any angle, so that it is possible to connect with any motion, of whatever kind, wherever it may

Mr. J. J. deKinder described the repairs to the 36-in. Belmont Submerged main, Philadelphia, recently made by him. The specially novel feature of this undertaking was a floating cofferdam, the bottom of which was built around the main, and the whole structure kept in exact balance, during freshets, etc., by two water-tight scows, suspended on its sides, into or out of which water was pumped to regulate the weight.

The rock lay so near the river bottom as to render a sheet-pile structure impossible.

W. Bugbee Smith introduced the subject of the Fire Protection of Mills. Mills must be properly built and furnished with adequate fire extinguishing apparatus. The best construction has been found to consist of heavy wooden posts and girders, solid plank floors and roof. The usual fire extinguishing apparatus consists of water buckets, hydrants and hose. In addition to this, some mills are furnished with perforated sprinkler pipes, running lengthwise through the mill, perforated with holes $\frac{1}{10}$ inch diameter and about nine inches apart. In case of a fire, by opening a valve outside of the building, water is let into the pipes and on the fire. The objection to this system is the fact that the water is not confined to the spot where the fire occurs, but is distributed over such a large area that much damage is done by it. It also requires human agency to make it effective.

To overcome these objections, automatic sprinklers, have been invented. These are valves, placed on a system of pipes near the ceiling and opened by the heat of the fire. They are kept closed by means of a fusible solder which melts at about 166° Fahr. The heat rising from a fire melts the solder joints of the sprinkler immediately over it, and thus the water is put just where it is needed.

There are two general classes of automatic sprinklers, the sealed, such as the Parmelee, Burritt, Rose and Bishop; and the sensitive, such as the Grinnell, Burritt, Brown & Hall, and the Kane. After describing the methods of piping a mill for each of the classes, samples of the above-mentioned sprinklers were exhibited and their peculiarities explained.

The automatic sprinklers have been in use about twelve years, and recent tests show that the fusible solder has not lost its strength and sensitiveness in that length of time, though ex-

posed to pressure and water hammer.

The effectiveness of automatic sprinklers s fire extinguishers is shown by the fact, that out of 110 fires originating under them and of which the damage is known, for 67, or 60.9 per cent, of the whole number, no damage was claimed; for 12, or 10.9 per cent,, the damage was less than \$250; for 8, or 7.2 per cent., between \$250 and \$500; for 11 or 9.9 per cent., between \$500 or \$1,000; for 12, or 10.9 per cent., between \$1,000 and \$20,000.

The Secretary exhibited, for Mr. S. L. Smedley, a photo-lithographic reproduction of a topographical map of Philadelphia, by John Hills, 1796, and pointed out some of the remarkable evidences of its great accuracy in

dctail.

Mr. Francis Lightfoot, of West Chester, introduced by the Secretary, explained a model of a Rail Joint in which no plates or loose pieces are required, the ends of the rail being lapped and bolted together through oblong slots.

November 1st, 1884. — President William Ludlow in the chair.

The Secretary presented, for Mr. A. W. Sheafer, Notes upon the Relative Cost of Haulage in the Anthracite Mines of Penna., by Mules and Locomotives. These embodied the results of investigations by Mr. Thomas H. Phillips, Supt. Kalmia Colliery. The results are as folbuys: Cost per ton per mile: by locomotive, $\frac{6}{10}$ cents, by mules $1\frac{82}{100}$ cents; saving, per ton per mile by locomotive, $1\frac{22}{100}$ cents. This includes operating expenses and depreciation, but does not include the additional number of cars and turnouts and repairs to roads, required for mule service.

The Secretary also exhibited for Mr. Sheafer, a set of Electrical Photographs of the Kohinoor Colliery Mine Workings. The exposures were from 20 to 30 minutes, and the results are ex-

cellent.

The Secretary exhibited the Bush Interlocking Rail Bolts, which interlock within the tie under the middle of the rail. They are specially intended, it is believed, to resist the lateral strain of the train upon curves.

Mr. Thomas M. Cleemann continued some previous remarks that he had made on the

Strength of Wrought Iron Columns, showing how some recent experiments by Mr. James Christie, at the Pencoyd Iron Works, gave values of the constants in Rankine's formula somewhat different from those generally used, and which would, therefore, be better to adopt, for calculating their strength, in structures of

American iron.

In discussing the above, Mr. James Christie stated that the experiment referred to by Mr. Cleemann were subsequently supplemented by similar experiments on steel, and a basis established for the relations existing between steel and iron compression members for structures. In addition to the practical results obtained, the experiments were of peculiar interest, inasmuch as they add additional confirmation to the ordinary theory of flexure as propounded by Euler a century ago., Experiments on beams of iron and various grades of steel, show a practically uniform elasticity, however different the materials may be in ultimate tenacity. When the lengths of column are so great in proportion to cross dimensions that failure will occur almost entirely by bending, then the elasticity of the material is the sole measure of its resistance, and the common theory of flexure will apply The experiments showed that when certain ratios of length to cross-section were reached, uniform resistance occurred between iron and steel, a fact, he believed, not heretofore known.

Capt. O. E. Michælis presented a blackboard description of what he was allowed to see at the recent exhibition of the "Keeley Motor" in

Philadelphia.

ENGINEERING NOTES.

CONSTRUCTION OF A DRY-DOCK IN QUICKSAND. J By — ZIMMERMANN.—This dock was built at Hamburg for the Hamburg-American Steam Packet Company. The only available site was a narrow strip on the Bank of the Elbe, perpendicular to the river, partly below high water, and the soil so loose and porous that it would only stand at a slope of 1 in 4. The excavation was 390 feet long, 66 feet broad, and about 23 feet below low-water level as a maximum.

Want of space precluded the formation of a cofferdam, of several rows of sheet piles of varying heights, which would have been the safest arrangement, so it had to be constructed of a single line of sheet-piling, which not only had to support the entire pressure of the surrounding soil, but, owing to its unavoidable imperfect watertightness, allowed the water to percolate through the sides. The first step, therefore, was the setting up of four turbines for pumping out the water. The work demanded of them was the lifting of 15,275 cubic yards, a maximum height of 23 feet in threeand-a half hours; but they did it perfectly in half that time—that is, they lifted on an average 2.42 cubic yards per second.

In order to limit the depth to which the piles had to be driven as much as possible, the bottom of the dock was not made horizontal, but rounded, to correspond with the form of a

below low-water level was sufficient. space enclosed by the piling was then dredged out. The concrete employed for the foundation was formed of 9 parts Luneburg lime, 7 trass, and 16 sand, mixed with twice that volume of broken stone, and was at first shot out for the entire thickness of the floor of the dock at once, by means of a wooden shoot or funnel attached to a traveling crane; but this arrangement did not answer well, for the shoot often splintered and broke, so an iron one had to be substituted. After the concrete had lain three months under water, the water was pumped out, and the concrete, though not perfectly set, was found sufficiently water-tight. Splinters of the wooden shoot were found in the concrete floor, and their removal caused strong springs or leaks, but these were successfully stopped by iron-cement.

On the concrete floor the side and front walls were built of brickwork, and carried up to summer flood-level, with a rebate or recess for a caisson, and all round the dock is a quaywall reaching above highest flood-level.

After a time it was observed that the butting of the caisson against the walls loosened the mortar, and the recess was not watertight, but it was made completely so by a facing of planed cast iron with concrete backing.

The weight of the empty dock alone is not sufficient to resist the upward thrust of the water at very high tides; but when loaded with the weight of a ship there is, of course, an abundant margin; and when no ship is in dock it is arranged that so much water shall be admitted as will satisfy the conditions of safety. The work was carried out in 1868 to 1870, and cost £65,000.

IRON AND STEEL NOTES.

ONSTITUENTS OF STEEL.—At the recent meeting of the Iron and Steel Institute, Mr. I. Lowthian Bell in the discussion of a paper on crucible steel, said, some importance seemed to be attached by Mr. Seebohm to the possibility of manganese existing in possibly two forms in steel. He had made no experiment with a view of ascertaining that, but it might interest Mr. Seebohm and Mr. Snelus, who also spoke on the subject, to know that not only carbon, but, as he believed, manganese was also occasionally separated in the way that carbon was, because upon one or two occasions, noticing a species of excrescence, as it were, on the face of pig-iron run from the blast furnace, he had this matter, which was silica in appearance, analyzed, and found it contained not only a certain portion of carbon, but a considerable quantity of manganese, and also of silica—silica in such a state of mechanical texture as left no doubt at all on his mind that, in point of fact, the silicon had been extruded from the iron itself and oxidized as it met the air, and thus formed silica. He quite agreed with what fell from Mr. Seebohm as to the desirability of the chemist being appealed to, perhaps even more urgently than he had yet been appealed to, with regard to explaining certain differences in the quality of steel, and, indeed of iron, generally. vessel, so that to drive the piles down to 23 feet If the chemist up to that time had not succeeded in furnishing an explanation for all those led to the necessity for the re-armament of our differences, gentlemen must remember that the science of chemistry as applied to iron, certainly in this country, was somewhat new, and that the quantity of matter uccessarily very seriously affecting the quality of the steel was so minute that they could scarcely be surprised if the researches of chemists had not yet mastered with sufficient exactness all the details required for ascertaiuing and detecting the preseuce of matter in such small quantities as were required for effecting the object he had just referred to. He might state that only recently, at the Monkbridge Iron-works, they were making irou, and they found it to be very red short. Mr. Kitson sent a specimen to him in order that he might ascertain if possible, the cause of this. Believing it possible that occluded oxygen might be at the root of the evil, he had some experiments tried upou the old lines, aud found uothing to induce him to believe that oxygen was at the root of the evil; but happening to fall upon a recently discovered method of estimating the quantity of oxygeu in iron, he had that tried, and theu he found that in the red short iron there was fully double the quantity of oxygen in some form or another thau there was in the specimens that were not red short. He merely meutioned this circumstance to show that they must not be impatient, but must work diligently and carefully in order to make themselves properly acquainted with all the circumstances and conditious which affected the quality of the material in the manufacture of which they had so great an interest.

RAILWAY NOTES.

RENOH RAILWAY ROLLING-STOCK.—There are altogether, on French railways, 6,893 locomotives, of which 2,836 are passeuger, and 4.067 goods engines. There are also 15,432 carriages, of which 3,208 are first-class, 5,315 second-class, and 6,909 third-class, together with 182,089 wagons. As regards the principal companies, the following are the figures: Northern, 1,138 locomotives, 2,021 carriages, and 33,971 wagons; Eastern, 922 locomotives, 2,359 carriages, and 22,401 wagons; Western, 1,045 locomotives, 2.881 carriages, and 17,465 wagons; Orleans, 970 locomotives, 2,100 carriages, and 40,433 wagons; Paris - Lyons - Mediterraneau 1,960 locomotives, 3,489 carriages, and 62,200 wagons. ---

ORDNANCE AND NAVAL.

THE HEAVY GUNS OF 1884.—This formed the subject of a lecture delisubject of a lecture delivered by Colonel E. Maitland, R.A., superintendent of the Gun Factory, Woolwich, before the Uuited Service Institution, on June 20. The walls of the theater were covered with diagrams of the latest piece of ordnance and sections of breeches, whilst the floor was occupied by a steel cannon and the breech of one of the new pattern interrupted screw breechloading guns Colonel Maitland said this was the time for laying before the public as clear an exposition as possible of the subject, which was one of national

naval and military forces, the progress now made in that re-armament, and the comparative efficiency of the heavy guns of 1884 in England and in the other chief countries of the world. The chief causes which had led to the necessity for the changes in our armament were-first, the improvement in powder; secondly, the improvement in mechanical appliances; and, thirdly, the improvement in production of large masses of steel. These considerations had affected the great continuetal powers, for they also were re-arming extensively, though the changes being made on the Continent were more gradual and less radical than our own. In the latter part of the seventies (the period between 1869 and 1880) Eugland certainly fell behind in the artillery race, but not to the extent supposed by mauy who had not studied the subject. As a matter of fact the old short breechloaders of the Continent were just as obsolete uow as the old short muzzle-loaders of England, and up to 1875 or 1876 the British artillery was as good as auybody else's. Then came a period of stagnation, and we fell to leeward. This country, however, had not been caught napping by an important war, but iu waiting had got the best of the artillery contest. Colouel Maitland then, for the information of non-artillerists, dealt with some of the technicalities of the gunner's craft, and explained the improvements which had occurred in the makiug of gunpowder, one improvement being an increased energy given to the projectile by the slowing of the powder, so that it should burn while the projectile was traversing the bore and increase in burning until the projectile was about to leave the muzzle. He discussed the important question of powder at length, and showed that the improvements in it had rendered breechloading in the guns to be an absolute necessity, as the guns had now to be made so long that loading from the muzzle became practically impossible on service, and the projectile had to be held fast until a pressure of from 1 ton to 2 tous per square inch was set up in the chamber, which could only be done in breech-loading guns. He spoke warmly of the promptitude with which Colonel Brackenbury, of the Woolwich Gunpowder Factory, had grappled with the difficulties of giving a suitable powder for improved English guns. Having referred to the cocoa powder of the Germans -a secret-Colonel Maitland dealt with the subject of breechloading and remarked that a satisfactory closing of the breech was not accomplished by any nation until after the Franco-German war of 1870-71, after which period Krupp entirely remodeled his breech fittings, and the French adopted an entirely new method of obturation, invented by Dr. Bange, of the French artillery. Colouel Maitland then stated that we had in haud guns of an efficient character up to 110 tons. He next spoke upou the Krupp system, the French marine system, the French land service system, and, lastly, upon the improvements which had been adopted in some of our own guns, the trials of these systems, and the avoidance of some defects disble of the subject, which was one of national covered in working. He presented a section of importance, setting forth the causes which had the Elswick gun of 110 tons, being manufactured for the government by Sir W. Armstrong, Mitchell & Co. This gun, he said, was entirely of steel, and had three layers of hoops over the breech-piece. In this gun there would be several important improvements upon the 100-ton gun of the Italian government. As to the adoption of steel for breechloaders, he justified the adoption of the metal, now thoroughly tested by German experience, and declared that England, in coming last, had really got the best forged steel construction known in guns. considered that England had obtained all the advantages of France and Germany combined. and, moreover, not being hampered by the necessity of utilizing old material, we had been able to devote all our euergies to new guns of the best quality, instead of altering old guns of inferior type. We had, moreover, greatly extended the ballistics of our guns, and had conferred on them uusurpassed powers in proportion to their weight. In conclusion, he said that now the time had arrived for the country to face the question of re-armament seriously, to grant the money, and to push on the manufacture. After remarks made by several speakers upon different points in the lecture, the discussion was adjourned.

THE TORPEDO FITTINGS OF THE NAVY.—In the ships of war recently built and in the ships of war recently built and in those now in course of construction, the fitting of underwater torpedo gear has been abandoned, the experience derived from the practice of the Inflexible not having been altogether satisfactory. Ships designed for exclusively torpedo service, such as the Vesuvius, the Polyphemus, and the Scout (which is now being built on the Clyde) may continue to be provided with submerged projectiles, but even in these the torpedoes will probably be only discharged from the stem ports in consequence of the difficulty of expelling them from the broadside of a ship under way and the impossibility of firing them in a straight line. The best results have hitherto been obtained from the stem tubes, aud from the great accession of speed which has been realized by the improved Whiteheads and the greater impulse which is communicated to them by the general adoption of the air-gun system, there is now no louger any danger to be apprehended from the projectile being overtaken and exploded by the ship from which it has been discharged. This desirable direct ahead fire has up to the present time been secured by two methods. In the Polyphenus, for instance, as in the similar case of the Italian turret-ship Duilio, the torpedo port is cut in the ram itself. This system has the obvious disadvantage of seriously weakening the spur and its attachments, and thus conducing to the crippling of the ship if not to its actual disablement. Provided a fair blow be delivered by the ram there will be no necessity to discharge a torpedo simultaneously with the blow to secure the complete destruction of au enemy; but should the blow, as happened in the case of the Defence and the Valiant, be deflected by a change of helm on the part of the enemy, the probability is that the spur of the Polyphemus would be so far disabled as not only to prevent her ramming a second time, but to prevent her Md.: Naval institute.

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using her torpedo armament. In the Inflexible, on the other hand, direct ahead fire is obtained by launching the torpedo over the stem by a sliding bar from above, a method which exposes the mechanism and the men handling it to the torpedo guns of an enemy. A new arrangement is now being introduced into the Camperdown, building at Portsmouth, and will also be embodied in the Scout and the Benbow. In addition to the four socket tubes on the broadside having a rauge of 70 degrees before and abaft the beam, or 20 degrees in a fore and aft line. the Camperdown is having a torpedo port worked in her brass stem on a level with the main deck and consequently high above the water line and her submerged prow. The gear and the men will consequently be well under cover. The torpedo, which is 16 feet long and 14 inches in diameter, is inserted in a steel cylinder of just sufficient dimensions to contain the projectile, and having a brass lining in which the grooves along which the T pieces of the torpedoes run are cut. The highly compressed air is admitted at the rear of the tube and in direct contact with the torpedo. In the old system the impulse was given by means of a piston, the blow from which when the engine was not in touch with it, was sometimes violent enough to injure the delicate mechanism of the torpedo. When everything is ready for firing, a touch of the firing key releases a brass ball magnetically held in position, the fall of which is made to rotate a lever, which in its turn releases the safety pin, and the torpedo is blown out of the ship. The only mishap which could possibly attend this method is the discharge of the torpedo before the port door had been opened, and the consequent explosion of the missile on board. This might be supposed to be an imaginary danger, but it has been practically provided against by an arrangement of levers. The port itself is elliptical, to allow for the fall of the torpedo in escaping from the ship; but the true uature of the parabola described by the torpedo in falling remains to be determined by careful observations. As the projectile leaves the tube a stud trips the trigger and sets the propelling eugines in motion. -London Times.

BOOK NOTICES

Publications Received.

DEPORT of the Commissioner of Education for the year 1882-83. Washington Governmeut Printing Office.

Annual Report of the Chief of Engineers,

United States Army. 1884.

Monthly Weather Review for September.

Washington Signal Office. Hydraulic Tables. Compiled by John W.

Hill, M.E. Ciuciunati: Robt. Clarke & Co. House Drainage as Constructed by the Durham House Drainage Co. By Wm. Paul Gerlard. New York: D. Vau Nostrand. Price 50 cents boards, \$1.00 cloth.

PROOEEDINGS OF THE UNITED STATES NAVAL INSTITUTE. Vol. X. THE ESTABLISHMENT OF STEEL GUN FAOTORIES IN THE UNITED STATES. By Lieut. W. H. JAQUES, U. S. N. Anuapolis,

The subject of this volume is of deep interest to many. The author has aimed to show the necessity for the manufacture of steel guns in this country, and to provide a manual of reference for those who desire to know the details of the latest methods of manufacture.

The methods pursued in England, France, Germany, Russia and United States are described and fully illustrated by diagrams.

An enumeration of the machines and tools for a plant for gun manufacture, aud the "General Summary of the Guu Foundry Board" close the volume.

TREATISE ON THE ADJUSTMENT OF OBSERVA-A TIONS. By T. W. WRIGHT, B.A., late Assistant Engineer, United States Lake Survey.

New York: D. Vau Nostrand.

The method of obtaining the most reliable result from a series of observations or measurements, when such observations are multiplied for the sole purpose of securing accuracy, is a subject of profound study, which is alike profitable to the student of theory or to the practical worker. The author of the present treatise is fully in sympathy with both classes, and, moreover, exhibits the capabilities of au instructor.

The increasing demand for better accuracy in surveys of all kinds has been responded to by the production of better instruments. But given the best instruments and the best observers, the question of how to obtain the best results is still an open one. To the importance of this question, the attention of American studeuts has not been heretofore sufficiently awakened. This treatise will be found to be a valuable stimulus to learners who aspire to the performance of good work in Surveying,

Astronomy or Physics.

The introductory chapter fully sets forth the nature of the work to be accomplished, viz.: the elimination of the effects of errors in measurements of various kinds, and describes the sources and kinds of error whether inherent or accidental in either the observer or instrument, or external to both as in the atmospheric couditions; and summarizes the conditions as follows: "When all known corrections for instrument, for external conditions, and for peculiarities of the observer have been applied to a direct measure, have we obtained a correct value of the quantity measured? That we canuot say. If the observation is repeated a number of times with equal care different results will in general be obtained.

The reason why the different measures may be expected to disagree with one another has been indicated in the preceding changes. There may have been uo change in the conditions of sufficient importance to have attracted the observer's attention when making the observations, but he may have haudled the instrument differently, turned certain screws with a more or less delicate touch, and the external conditions may have been different. What the real disturbing causes were he has no means of knowing fully. If he had he would correct for them, and so bring the measures into accordance. Infinite knowledge alone could do this. With our limited powers we must expect a resi-

duum of error in our best executed measures. and, iustead of certaiuty in our results, look

only for probability.

The discrepancies from the true value duc to these unexplained disturbing causes we call errors. These errors are accidental, being wholly beyond all our efforts to control. As soon as they are known to be constant, or we learn the law of their operation, they cease to be classed as errors.

A very troublesome source of discrepancies in measured values arises from mistakes made by the observer in reading his instrument or recording his readings. Mistakes from imperfect hearing, from transposition of figures, and from writing one figure when another is intended, from mistaking one figure on a graduated scale for another, as 7 for 9, 3 for 8, etc., are not uucommou. These also must be classed as accidental errors, theoretically at least. Haviug, therefore, taken all possible precautions in making the observation, and applied all known correctious to the observed values, the resulting values which we shall in future refer to as observed values may be assumed to contain all accidental errors. We are theu brought face to face with the question, "How shall the value of the quantity sought be found from these different observed values?"

This is followed by a brief syuopsis of the mathematical principles involved in the treatise: Probabilities, Definite Integrals, Taylor's Theorem, Interpolation, and Periodic Series. This synopsis is only just full enough to inform the reader in advauce of the stock of mathematical knowledge requisite for the mastery of the treatise. It is only intended to remind,

uot to instruct him.

The second chapter deals with the Law of Error, and we believe will be found full of interest to the mathematical student. The author shows how the accepted methods were evolved, and presents the earlier processes in historical order.

The chief topics of this chapter are: The Arithmetical Mean; Law of Error of a Single Observed Quantity; Law of Error of a Linear Function of Independently Observed Quautities; Comparison of the Accuracy of Different Series of Observations; The Probability Curve; The Law of Error Applied to au Actual Series of Observations; Classification of Observations.

There is an important appendix to this chap-

ter at the end of the volume.

Chapter III. treats of the adjustment of Direct Observations of One Unknown Quantity. The principal topics are: Observed Values of Equal Quality; Observed Values of Different Quality; Observed Values, Multiples of Unknown; Precision of a Linear Function of Independently Observed Values.

This chapter coutains a large number of examples of "Mean Square" and "Probable Er-Also two appended notes relating respectively to Weighting of Observations and Rejection of Observations. In this latter note we find the following remark regarding a criterion for rejection, with which we believe all practical workers will find themselves in

"It may be stated, as a general rule, that criterions are apt to be most highly esteemed by those who look at the observations from a purely mathematical rather than from a praetical observer's point of view. The latter is, without doubt, the true standpoint. Every observer will eonsciously or unconseiously construct a criterion suited to the sort of work he This criterion will not necesis engaged in. sarily be founded altogether on mathematical formulas. Indeed, most likely it will not be. Nor does it follow that the criterion adopted in any special series is of universal application or will receive universal assent. In the process of weighting, the observer will not assign weights always as the inverse squares of the "mean square error." It is often better to assign them arbitrarily, from a feeling founded on a general grasp of all the eireumstanees eonneeted with the making of the observations. In like manner, and in this same feeling, he will found his criterion for rejection. There is no uniform rule for weighting; neither is there one for rejection."

Chapter IV., on Adjustment of Indirect Observations, deals at much length with Determination of Most Probable Values. This is followed by: Precision of the Most Probable (Adjusted) Values; Precision of any Function of the Adjusted Values; Average Value of the Ratio of the Weight of an Observed Value to its Adjusted Value and Artifices of Elimina-

tion.

The theoretical part of the treatise is completed in Chapter V., which presents the consideration of the adjustment of a series of observations which are not entirely independent of each other. This is termed the Adjustment of Conditional Observations. A general statement of the character of the problem is followed by: The Direct Solution (Independent Unknowns); The Indirect Solution (Method of Correlates); Solution in Two Groups; Solution by Successive Approximations.

Examples are interspersed as in the preced-

ing chapters.

The remaining portion, nearly half of the volume, exhibits applieations of the principles elueidated in the foregoing chapters. examples are mostly from American practice.

They are divided as follows:

Chapter VI., Triangulation; Chapter VII., Base Line Measurements; Chapter VIII., Leveling; Chapter IX., Graduation of Line Measures, and Calibration of Thermometers; Chapter X., Empirical Formulas and Interpolation.

The work throughout exhibits signs of careful preparation, and we believe it will be regarded as a very valuable contribution to Eng-

lish seientific literature.

ORESTRY IN THE MINING DISTRICTS OF THE URAL MOUNTAINS. Compiled by John CROUMBIE BROWN, LL. D. London: Simpkin, Marshall & Co.

This work, like the later ones of this industrious writer, is carefully compiled from reliable

sources and is exceedingly compact.

The ehapters present in order the following subjects: Journey from St. Petersburg; Forest dueed, the best methods of taking them, and

Exploitation in Ufa; Mishaps in Traveling; Russia and her People; The Ural Mountains; Metallurgy; Forests; Depressed Condition of Mining and Manufacturing; Forest Exploitation; Abuses in Exploitation of Forests; Occasion of Diminished Supply of Wood; Glimpses of Life; Laboring Population: The Conquest of Siberia.

A COURSE OF QUALITATIVE CHEMICAL ANALYSIS. By W. GEO. VALENTIN, F.C.S. Revised by W. R. Hodgkinson, Ph. D. Sixth Edition. Philadelphia: P. Blakiston, Son &

The merits of Valentin's work are well known to workers in the laboratory. The notation is that of Frankland, while the methods of separation are largely original with the author and

Students using the text as a guide to practical analysis, find the full directions for their work

especially convenient.

The examination questions which are appended to each section, serve to direct the learner's attention to the more salient points. Some advantage to the student is also afforded by oeeasionally presenting the graphic symbol of a compound.

The work is particularly good in the matter of detection of the acids and in the reactions of the rare metals. The latter portion represent-

ing the later additions to the book.

THE STEAM ENGINE INDICATOR AND ITS USE. By WILLIAM BARNET LEVAN. New York:

D. Van Nostrand. The literature of the indicator is by no means seanty. There are not wanting essays upon this instrument which treat, more or less lucidly, upon its peculiarities, but many of them presuppose a certain familiarity with the indicator upon the part of the student, and plunge, in medias res, on the first pages. In regard to the indicator itself, a revival is in progress. A class whom it is very essential to educate have taken it up and are availing themselves of its offices. They know nothing of it beyond the fact of its existence and are exceedingly anxious to learn. It is manifest that, for such readers, the treatment should be severely simple and rudimentary. It is difficult for many writers, who essay the task of teaching beginners, to comprehend this, this after brief allusions to the object of the indicator they proceed, without loss of time, to thermal units and adiabatic curves. Moreover. many works on the indicator are useless to students by reason of the mathematical processes of elucidation employed. It is natural that an expert should eough his expressions in the shortest and most eoneise terms, but this cuts off a great many from availing themselves of the

vious to require no pointing out. In The Steam Indicator and Its Use, by Wm. Barnet LeVan, provision has been made for the class mentioned before. They are specially addressed, in point of fact, in simple language and by plain diagrams. Starting with a detailed description of the indicator, the author proceeds by easy stages to simple diagrams, explaining in terse language how they are pro-

instruction given, for reasons sufficiently ob-

lastly, how to compute the areas enclosed. All large number of dynamical problems rest mainly this is accompanied by the necessary diagrams, so that any person who is fit to be about an engine at all can use the indicator practically.

Another point in favor of the work for those for whom it is compiled, is its low price. issued from the press of D. Van Nostrand & Co., in their admirable Science Series, a form which has rendered many valuable papers popular, and insured a reading for scientific treatises, taken from high class publications which the multitude would never see. This work on the Indicator is appreciated by those for whom it is written, and is selling well.

A NALYTIC MECHANICS. By E. A. BOWSER, A Prof. of Mathematics and Engineering, Rutgers College, New Brunswick, N.J.; D. Van Nostrand, Publisher. 12mo. cloth. Price, \$3.00.

An American text-book on Mechanics that would present its leading principles in a clear and simple way, and at the same time furnish a substantial preparation for its higher branches, has long been desired. The increasing appli-cations of this branch of mathematics to the practical problems of engineering and architecture have made a knowledge of it necessary to success in these departments. No one can appreciate the advances made in the theories of Light, Heat and Electricity, who is not familiar with the methods of Dynamics.

The text-book of Prof. Bowser is admirably fitted for filling these conditions. He has succeeded in happily combining simplicity and clearness of treatment with a full exposition of some of the more difficult parts of the science.

The practical bearings of the principles are illustrated by their applications to the mechanical powers, while attention has been given to the requirements for a preliminary training in celestial and physical mechanics. The work involves the use of Analytic Geometry and the Calculus, and in itself is a valuable discipline in these branches of mathematics.

The chapters on "Moment of Inertia" and "Center of Gravity," furnish a fine illustration of the use and power of the calculus. The practical way in which the author passes from theoretical formulæ by means of numerous and wisely selected examples, to actual cases requiring arithmetical calculation, is a marked and valuable feature of the book, and makes an otherwise difficult subject, attainable and useful.

The chapter on Friction goes a great way toward divesting many of the problems of mechanics of their usually unreal character, in giving methods for dealing with the cases of bodies not perfectly smooth—cases of occurrence in things as we find them.

An entire chapter has been devoted to "Work and Energy," and these important terms are fully explained and their physical significance definitely pointed out.

Prof. Bowser has made a separate division of Kinematics—a science which bears the same relation to Dynamics that the science of Mechanism does to Mechanical Engineering.

The distinction between motion, regarded merely as change of place, and motion as produced by force has long been recognized, but seldom finds its way into our text-books.

on the relations between velocities, accelerations, &c., considered without reference to their causes, and there is a gain in clearness in making their treatment a separate part of the subject.

Under Kinetics the motions of bodies under the action of forces have been considered. The problems of central forces are taken up and illustrated, by showing that the Laws of Kepler are a necessary consequence of the law of gravitation.

A suggestive and instructive feature of the book is the many references to the standard works on the different branches of mechanics.

The treatment throughout is plain, direct and complete, and the arrangement is nicely adapted

to purposes of instruction.

The book is of convenient size, neatly bound, and printed in clear type

MISCELLANEOUS.

ON THE MEASUREME 1 OF WILD-PRESSURE—INCOMPLE TWESS OF BORLA'S FORMULA.—By Dr. Fines.—Lorda's formula for deducing pressure of wind from elocity is F=C×SV2 C being a constant coefficient for a certain plate, S the surface in square meters, V the velocity of the wind in meters per second. I the pressure of the wind in kilograms per square meter. C varies with size and shape of plate. Borda gives the following values:

C=0.092 kilo, for plain plates of 0.011664 sq. me. 0.0262440.100 0.1040.0590490.1200.929000

The first three of the above values are given by Borda, the last by Rousse. Later, Navier found that in the case of movement in the atmosphere at 10° Centigrade, under the normal pressure C=0.1278. Thibault, however, found the value of C under the same conditions to be 0.1151. Dupré considered that Navier's formula, R=0.1278 SV², is the right one to use.

The author states that Borda's formula gives rise to two sources of error, one owing to inaccuracy in the formula, the other to its applica-tion. Though the size and shape of the plate are known, the reciprocal reactions of the different currents of air one upon the other are not; neither are their absolute velocities, the mean velocity only is known.

The ordinary anemometer is incapable of recording the velocity of the wind at the time (of only a few seconds' duration) of the most violent gusts. M. Renard, however, made observations during the violent storm of November 16, 1880. He found that during an interval of twenty-five seconds the velocity increased from 38 to 51 meters per second, and then diminished in the following twenty seconds to 35.70 meters, so that during this short interval the pressure varied from 325 to 136 kilograms per square meter. These observations, however, do not give the absolute maximum intensity which can have lasted only a few seconds, and may have been much higher than that above stated, and it is the absolute maximum velocity which is required for an exact application of Borda's formula.—Abstracts of Institution of A Civil Engineers.

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CHAPTER VII.— SEMI - INCANDESCENT AND INCANDESCENT LAMPS.

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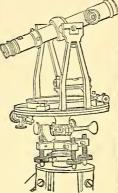
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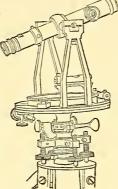
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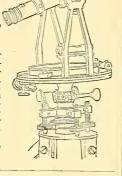
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REVISER'S NOTE.

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Commander F. B. McNair has permitted the use of his pamphlet on Seamanship Drills.

The chapter on the Laws of Storms is taken principally from the lecture of Lieutenant-Commander Thomas Nelson, vol. 5. Proceedings U. S. Naval Institute.

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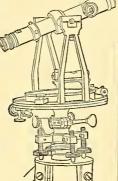
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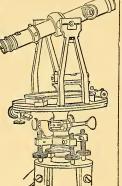
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